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RESERVOIR SEDIMENTATION MODEL WITH CONTINUING DISTRIBUTION, COMPACTION, AND SEDIMENT SLUMP

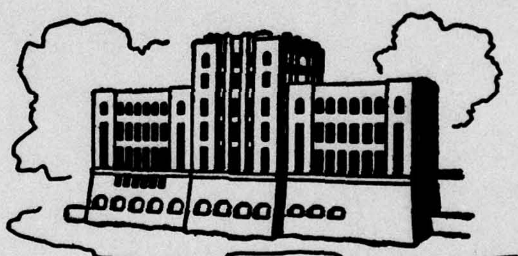
by

Thomas E. Croley II

K. N. Raja Rao

Fazle Karim

Sponsored by
Office of Water Research and Technology
Iowa State Water Resources Research Institute
(Title I Annual Allotment Projects No. A-054-IA, A-068-IA)



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PREFACE

This study was performed as part of a comprehensive investigation of reservoir operations for the Coralville reservoir, near Iowa City, Iowa. The change in the reservoir profile due to sedimentation with continued operation of the reservoir is an important consideration in the planning and design of various reservoir outlet works as well as in formulating an optimum operation plan for a reservoir. So, a need exists to develop a computer application technique to account for the entrappment and distribution of sediments in reservoirs, for use in conjunction with optimization techniques for reservoir operation. The computer model "SEDRES", developed and presented herein, will, hopefully, help fill this need. The present model incorporates a modification of existing empirical methods and procedures to account for continued compaction and sediment slump. The model has been generalized for application to other reservoirs.

ACKNOWLEDGEMENTS

The cooperation of the personnel of the U.S. Army Corps of Engineers, Rock Island, Illinois, and of the U.S. Geological Survey, Iowa City, Iowa, is gratefully acknowledged. They made available much relevant data for the Coralville reservoir.

This study was supported in part through the Title-I Annual Allotment Program, project numbers A-054-IA and A-068-IA of the Iowa State Water Resources Research Institute under Annual Allotment Agreement Nos. 14-34-0001-6016 and 14-34-0001-8017, respectively, with the United States Department of Interior, Office of Water Research and Technology.

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ABSTRACT

A comprehensive reservoir simulation scheme has been developed to estimate changes in the reservoir profile due to sedimentation over any length of reservoir operation. The model includes several input submodels, e.g., time series models for generating sequences of water inflow, sediment inflow, and evaporation, and an operating submodel to supply necessary input data to the sedimentation submodel, which forms the heart of the simulation scheme. The sedimentation submodel estimates the total volume of sediment trapped in the reservoir in a selected time interval, and then distributes this over the height of the reservoir, based on a modified version of Borland and Miller's (1960) empirical area-reduction method. This modification enables the use of the model for any interval of sedimentation, while Borland's original method is applicable only for large (10 years or more) sedimentation periods. Deposited sediments are compacted and necessary corrections are applied to remove anomalies caused by slumping due to differential compaction of different sediment components (sand, silt, and clay) in the vicinity of the "zero" elevation and at the sediment zone interfaces. The simulation model, at the end of each time interval, outputs the water outflow, the reservoir pool elevation, the volume of deposited sediment with its distribution over the reservoir height, the resulting new zero elevation, and the adjusted elevation-area-volume relationship.

The validity of the model was checked by application to the Coralville reservoir on the Iowa river near Iowa City, Iowa. The total period of simulation was 10 years (1958-68) and the intervals of correction for compaction and slump was varied from one week to 10 years. Close agreement was observed between the model results and the actual survey data. Larger intervals of correction were found to give better agreement with survey data. It has been demonstrated that the procedure for compaction and consequent slump corrections, as incorporated in the present model, significantly improves Borland's original procedure.

RESERVOIR SEDIMENTATION MODEL WITH CONTINUING DISTRIBUTION, COMPACTION, AND SEDIMENT SLUMP

I. INTRODUCTION

The various phases of the sedimentation process are: erosion, entrainment, transportation, differential settling, deposition, and the compaction of sediment. The chief agents governing sedimentation are rainfall, runoff, streamflow, and wind. The problems resulting from sedimentation are many and varied. Of these, the present report deals with the consequences of sedimentation in man-made reservoirs.

As a sediment carrying stream enters a reservoir with still water, the flow depth increases with progressive reductions in velocity. The reduction in velocity causes loss of sediment transporting capacity resulting in the deposition of sediment, along the reservoir bed. The coarse grained components (sand and gravel) of the sediment begin to deposit in the higher reaches of the reservoir and the fine grained components (silt and clay) are transported further into the pool. The actual location and manner of deposition of sediment along the reservoir bed depend on factors like the longitudinal slope of the original streambed, the shape of the reservoir, the particle size-distribution of the incoming sediments, the mineral characteristics of the clay-size sediments, the chemistry of the water, operation plan and outflow characteristics of the reservoir.

Usually, artificial lakes and reservoirs are provided with outlets for various purposes, including the sluicing of sediment. But experience with these reservoirs, during the last several decades, has shown that it is not possible to effectively release all the sediment entering the reservoir. As per Brune (1953), more than 90% of the incoming load is generally trapped. The obvious consequence of the entrapment of sediment is the loss of storage capacity of the reservoir. The sediment accumulation also adversely affects the functioning of reservoir outlets, recreational facilities and important installations in the backwater regions, if any.

Until 1940, reservoir planners held the view that the sediment invariably travels all the way up to the dam face and settles there. Following

this assumption, the designers provided what is known as "dead storage" in the reservoir extending from the original river bed up to a certain elevation, sufficient to accommodate the estimated inflow of sediment over the useful life of the reservoir. In some reservoirs "scouring sluices" were provided, for washing out the incoming sediment periodically. These reservoirs were neither able to confine the trapped sediment to the dead storage nor able to release it satisfactorily through the sluice gates.

Some of the big reservoirs that were constructed during the early part of this century had completed several years of operation by 1940. The extent and rate of sedimentation in some of these reservoirs were found to be alarming. In order to estimate quantitatively the loss of storage in the reservoirs, sedimentation surveys were initiated. The results of these surveys and those conducted earlier are summarized in Miscellaneous Publication No. 1143 of the United States Department of Agriculture (1969). This publication covers the surveys up to the year 1965. Some of the subsequent studies relating to sedimentation surveys are indexed with abstracts in the National Technical Information Service publication NTIS/PS-75/886. Pais-Cuddon and Rawal (1969) carried out some qualitative studies relating to sedimentation in Indian reservoirs. Szechowycz and Qureshi (1973), utilizing some of the existing procedures, estimated the extent of sedimentation in Mangla Reservoir in Pakistan.

The findings of the sedimentation surveys have been very informative. The important conclusion drawn was that sediment starts settling right from the head waters down to the dam face, and is not confined to the lowest portion of the reservoir. Furthermore, most of the sediment that flows into the reservoir is trapped in the reservoir. Based on the information furnished by these surveys, empirical procedures for estimating sediment entrapment (Brune, 1953), distribution along the reservoir height (Borland and Miller, 1960; Moody, 1962), and compaction with time (Lane and Koelzer, 1943), evolved.

Recent research in the modeling of reservoir sedimentation concentrated on the solution of the governing equations of flow, e.g., the equations of motion and continuity for sediment-laden flow and the equation of continuity of sediment. Various numerical techniques, using finite difference schemes, were used to solve the governing equations for estimating changes in bed profile. However, the models developed so far in this category

do not take into account all the factors (e.g., density current, variable specific weight, compaction, transverse distribution, etc.) responsible for deposition or erosion of sediments in reservoirs. Murray, et. al.(1974) used a simplified technique to solve the governing equations in two parts, independent of each other: (a) backwater profile and (b) sediment transport computations. The method consists of the application of sediment transport equations at each successive reach and the amount deposited in each reach is computed as the difference in the sediments transported at the beginning and at the end of each reach. They used only bed load deposition and three different bed load equations. The model results showed good qualitative agreement with the shapes of deltas observed in some reservoirs. Fowler (1957) used a simplified relation of the form $C_n/C_1 = K\, u_*^n$ (C_n, C_1 = suspended sediment concentrations at section n and open river, respectively, u_* = shear velocity at section n; K,n are constants) to estimate deposition from suspended sediment between two sections. He estimated values of K,n for sand, silt and clay, based on observed data. This method was suggested for predicting development and growth of deltas. Thomas and Prasun (1977) solve the energy equation by the standard-step method and the sediment continuity equation by a finite-difference scheme. The model was verified with hydraulic models and field data and good agreement was observed. Chang and Hill (1976) developed a computer model to estimate aggradation and degradation of a flood channel. The energy equation and the continuity equation of flow were solved by the standard-step method for water surface profiles; the sediment continuity equation was solved by a backward finite-difference scheme. They also developed a program for simulation of delta formations. Combs, et. al.(1977) developed a model for computing sediment transport throughout a reach of river and for determining areas of scour and deposition. Chang and Richards (1971) solved the equations of continuity and motion by the method of characteristics and the sediment continuity equation by a finite-difference scheme. Computations of water-surface profile and sediment deposition were made in two parts. They applied the method to a hypothetical case and obtained reasonable patterns of deposition. Mahmood and Ponce (1976) developed a computer model of sediment transients, considering both bed load and suspended load. A coupled solution of the momentum and sediment continuity equations enables the numerical solution with longer time steps than are possible for uncoupled models. A linearized implicit numerical scheme was used to solve the governing

equations. The model has been applied to hypothetical examples, but not checked with observed field data. All the mathematical models mentioned so far are one-dimensional models; transverse distribution of sediments across sections were not accounted for.

The most recent work in the area is due to Lopez (1978), who has developed a mathematical model for flow and sediment routing through reservoirs. His model includes a jet flow theory which simulates the incoming river flow as a two-dimensional plane jet discharging into the reservoir. The model takes into account non-uniform grain size distribution, and transverse distribution of sediment (not well explained). Flow and sediment routing is done in a sequential mode. The numerical solution of the flow-routing model was developed by using a fully implicit finite-difference scheme. For sediment routing, an explicit finite-difference scheme was used. The time and space intervals for the numerical scheme must be selected, for stability and convergence, by careful numerical experiments. Application of the model requires calibration for selection of resistance coefficients and sediment parameters. The model has been applied to a flume model and to the Colorado River, upstream from the Imperial dam, with reasonable agreement.

Experience in the operation and maintenance of various kinds of reservoirs, over the years, has indicated that the extent of sedimentation depends chiefly on the quantity of sediment that flows in and on other factors like operation rules, size and shape of the reservoir, water inflow, water outflow, evaporation, etc. The interaction of these factors is too complex to permit an analytical approach to estimate quantitatively the order of sedimentation in a reservoir, over any desired length of time. However, it is found practicable herein to develop a computational procedure to simulate the process of sedimentation in reservoirs. The simulation provides for the representation of all aspects and phases of reservoir operation that influence sedimentation. The inputs to the model are water inflow, sediment-inflow, and evaporation. During each time interval of reservoir operation, water inflow is routed through the reservoir as per the desired operation rule and the outflow is estimated. The sediment entering the reservoir is distributed over the height of the reservoir and compacted. The distribution takes into account the particle sizes of sediment components, reservoir size

and shape, pool level, compaction of each layer of sediment with regard to its composition, age, etc. At the end of each interval of time, after the correction for reservoir evaporation is applied, the revised profile of the reservoir with regard to the elevation-area-volume relationship is computed. The model, constructed for computer use, is quite general and provides for application to any storage reservoir, with a choice of time interval of operation (weekly, monthly, etc.), total length of simulation, and operation rule. The details of the procedure are described in the ensueing sections of this report.

To illustrate the practical application of the procedure, the model is applied to a real life problem relating to the Coralville reservoir near Iowa City, Iowa. The Coralville reservoir on the Iowa River went into operation during the fall of 1958. Since its construction, three sedimentation surveys were conducted by the reservoir operators: the U.S. Army Corps of Engineers. Advantage was taken of these surveys to compare the results of the study with the actual sedimentation.

To implement this scheme of simulation,a computer program is written in FORTRAN IV for use on the IBM 360/65 computer at the University of Iowa. All phases of the computations in the program are explained sequentially in the ensuing sections. A listing of the program together with a sample output is included in appendix B.

II. SEDIMENTATION IN RESERVOIRS

The calculation of sediment accumulation and deposition and the resulting changes in the elevation-area-volume relationship with time is complex. The basic models are briefly described below in the order they are used in the computer calculations. These models are used to estimate the trapment, distribution, differential settling into zones, zero elevation, compaction of current amounts and all previously deposited amounts, correction to zero elevation due to compaction, sediment slump due to compaction at zero elevation, alterations of the reservoir elevation-area-volume relationship due to sedimentation, sediment slump at zone interfaces, redistribution of all earlier sediment layers to agree with the slumped profile, redetermination of sediment zones for each layer of compacted sediment after the current compaction, determination of "equivalent" uncompacted

sediment in each layer for use in the next time-period compactions, and redetermination of sediment zones for each layer of equivalent uncompacted sediment after decompaction for use in the next time-period compactions. These models are applied in each time period of the reservoir sedimentation simulation and they are detailed in this section as they are used during one such time period.

A. Sediment Entrapment

As sediment flows into the reservoir, a large fraction of it is trapped. In an attempt to predict the amount of sediment trapped, Brune (1953) has plotted an empirical relationship, based on records of 44 normally ponded reservoirs, between trap efficiency of the reservoir and the capacity-inflow ratio (see figure 1).

$$E_T = f(C/I) \tag{1}$$

where E_T = trap efficiency of reservoir (fraction); $f(\cdot)$ = functional form of empirical relation; C = capacity of reservoir, acre-ft; and I = annual inflow into the reservoir, acre - ft. This relationship is used for estimating the average trap efficiency for a year. As an approximation, for periods of time other than a year, the following relation may be used:

$$E_T = f\left(\frac{C}{I} \cdot \frac{N}{N_y}\right) \tag{2}$$

where I = inflow into reservoir in the time period, acre-ft; N = number of time intervals in the time period; and N_y = number of time intervals in a year. The result is the same as finding the average annual inflow over the years for $N > N_y$ or extending the inflow from a smaller period over a year for $N < N_y$. The estimated volume trapped is calculated from the trap efficiency and the amount of accumulated sediment inflow in the time period:

$$E = \frac{Q_s \cdot 2000}{\gamma \cdot 43560} \cdot E_T \tag{3}$$

where E = estimated volume trapped, acre-ft; Q_s = accumulated sediment inflow in the time period, tons; and γ = overall specific weight of the sediment, lb/cu-ft. The actual volume trapped may also be affected by sluicing operations for the reservoir. In this case the estimated volume

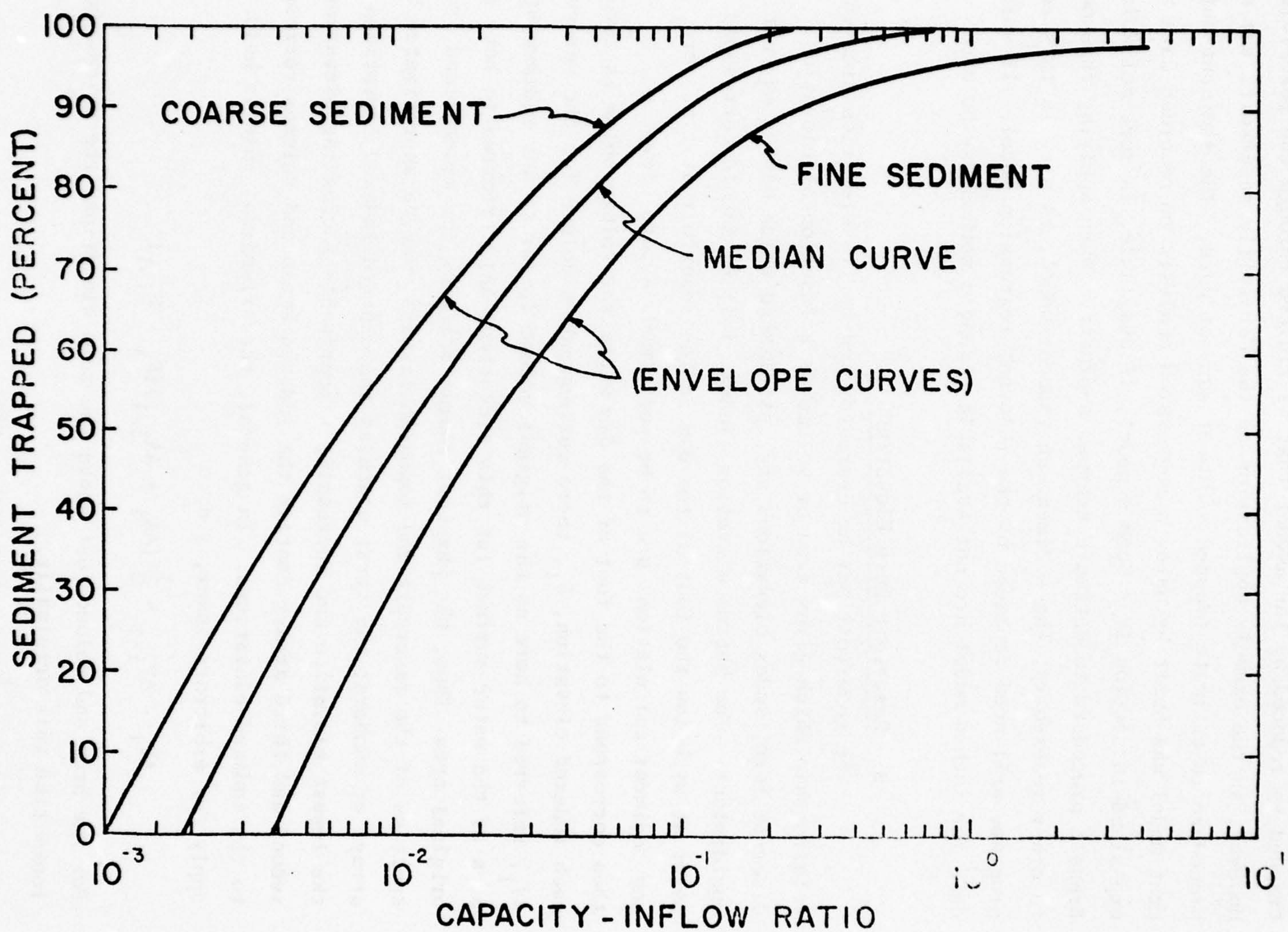

Figure 1. Trap Efficiency Curve (Brune)

trapped is reduced by the amount that is sluiced through the *reservoir*. However, in the example application to the Coralville reservoir, the above procedure to estimate trapped sediment was not used. The sediment entrapment model was built by using a regression analysis on recorded data as explained in section IV. Such a model, if available, is more reliable than Brune's procedure to estimate trapped sediment. When applying this model to other reservoirs, the sediment entrapment model, as used in this computer program, will need replaced by the relevant regression model. If sufficient data for such a model are not available, Brune's method may be used.

B. Reservoir Zero Elevation

The reservoir may be characterized by its elevation-area-volume relationship which gives area or volume as a function of elevation. In discrete form, index elevations are established which may or may not be equidistant. The bottom elevation (index, i=1) E_1 should correspond to a point at or below the foot of the dam in the reservoir at time zero, before any sediment calculations are to be performed. A zero elevation, E_z should then correspond to the foot of the dam where the volume below is zero. For each indexed elevation, E_i, *there corresponds a volume for the reservoir* AV_i, referred to here as the original volume (prior to any sedimentation) and an area of the water surface (at this elevation) AA_i, referred to here as the original area. Thus, the physical characteristics, as ascertained from inspection of the reservoir and topographic maps, may be approximated by three arrays of numbers; the first contains the ordered indexed elevations (i=1 is the lowest elevation and increasing i represents increasing elevation.) The second and third arrays contain the indexed areas and volumes corresponding to the indexed elevations. In general, the prismoidal rule is held to apply for arbitrary index, i.e.:

$$AV_i - AV_{i-1} = \frac{1}{2}(AA_i + AA_{i-1})(E_i - E_{i-1}) \tag{4}$$

For the area and volume just above the zero elevation, the prismoidal rule looks like this originally:

$$AV_2 = \frac{1}{2}(AA_2 + AA_z)(E_2 - E_z) \tag{5}$$

where AA_z = area (horizontal) of reservoir water surface at the zero elevation. AA_z may be greater than or equal to zero. It should be observed that all three arrays are monotonically increasing with the index i for practical reservoirs.

In each time interval, a fresh volume of sediment enters the reservoir. A portion of this incoming sediment fills the "dead storage" establishing a new "zero elevation" (elevation of sediment at dam face). It is necessary to determine this new zero elevation to estimate the distribution of sediment over the height of the reservoir (discussed subsequently). The new zero elevation is determined from a known value of sediment volume to be placed into dead storage and a knowledge of the elevation-area-volume characteristics of the reservoir (refer to figure 2). In figure 2, ΔV = volume of sediment above elevation E_i, to be placed into dead storage; E_z' = previous (prior to current period) zero elevation; DV = total volume of sediment to be placed into dead storage; E_z = new zero elevation, to be determined; E_i and E_{i+1} = indexed elevations just below and just above the new zero elevation; A_i, A_z, and A_z' = reservoir surface areas (prior to current period) at elevations E_i, E_z, and E_z', respectively; and V_i = previous (prior to current period) volume of reservoir at elevation E_i. A_i and V_i are determinable from the original array of elevation-area-volume (before any sedimentation) if the past sediment volumes are known. This is discussed subsequently. Linear interpolation is used throughout between elevations E_i and E_{i+1} to determine intermediate areas and volumes at intermediate elevations.

There are two cases for determining the new zero elevation. The first case corresponds to figure 2 where E_z' is below E_i. By using linear interpolation,

$$E_z = E_i + (E_{i+1} - E_i)(A_z - A_i)/(A_{i+1} - A_i) \tag{6}$$

By using the prismoidal rule,

$$\Delta V = \frac{1}{2}(A_z + A_i)(E_z - E_i) \tag{7}$$

By substituting E_z from eq. (6) into eq. (7) and solving for A_z,

$$A_z = \left[A_i^2 + 2\Delta V(A_{i+1} - A_i)/(E_{i+1} - E_i)\right]^{1/2} \tag{8}$$

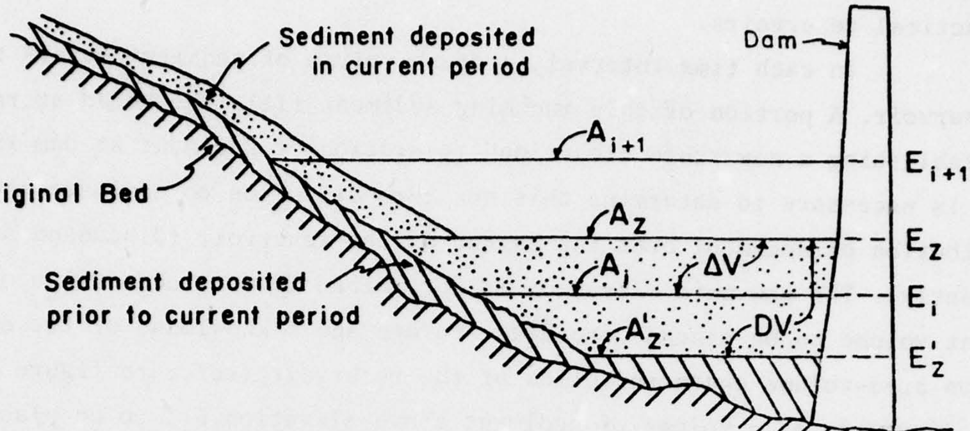

Figure 2. Sketch for Zero Elevation Computation

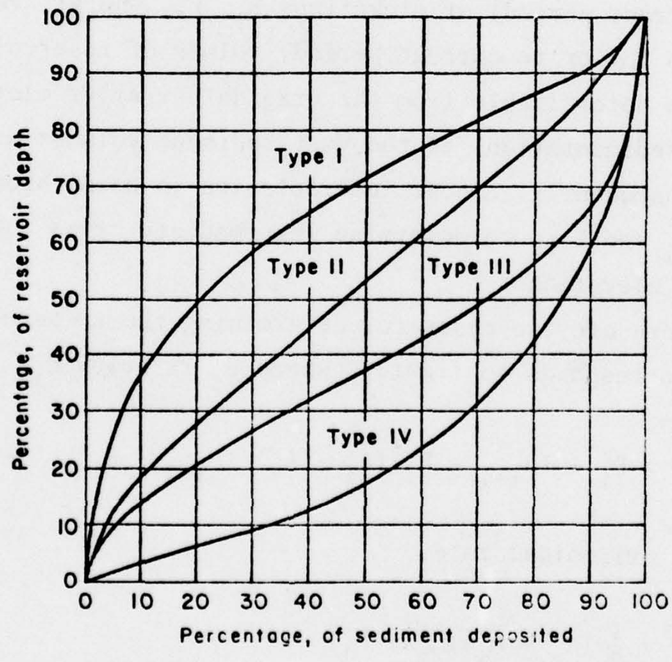

Figure 3. Type Curves [Borland and Miller (1960)]

By substituting A_z from eq. (8) back into eq. (6), E_z may be determined in terms of known quantities:

$$E_z = E_i + \frac{1}{b}\left[\sqrt{A_i^2 + 2\Delta Vb} - A_i\right] \tag{9}$$

where $b = (A_{i+1} - A_i)/(E_{i+1} - E_i)$. Furthermore, from inspection of figure 2:

$$\Delta V = DV - V_i \tag{10}$$

The second case is where E_z' is above or equal to E_i.

$$E_z = E_z' + \frac{1}{b'}\left[\sqrt{A_z'^2 + 2\Delta Vb'} - A_z'\right] \tag{11}$$

where $b' = (A_{i+1} - A_z')/(E_{i+1} - E_z')$. Furthermore,

$$\Delta V = DV \tag{12}$$

With known values of E_i, E_{i+1}, E_z', A_i, A_{i+1}, A_z', and DV, the new zero elevation (E_z) can be determined from eq. (9) and (10) or from eqs. (11) and (12). The computer program uses these equations as appropriate to determine new zero elevations after sediment is trapped but before distribution and compaction takes place for the current time period.

C. Sediment Distribution

The distribution of sediment volumes along the reservoir height is a complex phenomenon which has had some attention in the past. Borland and Miller (1960) devised a procedure called the "Empirical Area-Reduction Method" for distributing sediment that incorporates empirical distribution curves based on the type of reservoir. Moody (1962) has revised the procedure and fitted Beta functions to the empirical curves. According to this method, reservoirs are classified according to four basic standard type curves that were developed from actual resurvey data. A trial and error type computation is made using the "average-end-area" or prismoidal formula until the capacity computed equals the predetermined capacity. The resurvey data for 30 reservoirs were used to develop four standard type curves as shown in figure 3.

Based upon the analysis of the resurvey data, reservoirs are classified (Borlund and Miller, 1960) by the slope of the reservoir depth vs reservoir capacity plotted on log-log paper. Type I reservoirs have a slope between 0.22 and 0.28 and are typified by shallow lakes.. Type II reservoirs are found in floodplains and foothills and have a slope between 0.28 and 0.40. Type III reservoirs are found in hilly topography and have a characteristic slope on the log-log plot between 0.40 and 0.67. Type IV reservoirs are represented by narrow gorges and have characteristic slopes between 0.67 and 1.0. This information is summarized in figure 4 on which the data for the Coralville reservoir is also plotted with a slope of 0.34, indicating that it is a type II reservoir. The beta curve fit for a type II reservoir is (after Moody, 1962)

$$p = 2.487\, d^{0.57}\, (1-d)^{0.41} \tag{13}$$

where p = the dimensionless relative sediment area at a relative distance d above the zero elevation. The non-dimensionalization is made by dividing actual area by the area at the zero elevation and by dividing the actual depth by the total height of the sediment distribution in the reservoir (difference between maximum or average water surface elevation and the zero elevation). The procedure as outlined by Borland and Miller (1960) has been used here with minor modifications. After the amount of sediment to be distributed is determined, a portion of the sediment is placed in the dead storage against the dam, determining the new zero elevation of the reservoir. Then the remainder of the sediment is placed in increments along the remaining reservoir height according to the empirical area - reduction relationship for that particular reservoir type. The actual amount placed along the reservoir height depends upon the surface area of the reservoir at the zero elevation. The area of the reservoir at each elevation (relative height) is reduced by the empirical relative area, times the area of the reservoir at zero elevation. A modification here enables the use of a smaller area times the empirical relative area, thus decreasing the volume of sediment stored above the zero elevation.

$$H = E_T - E_z \tag{14}$$

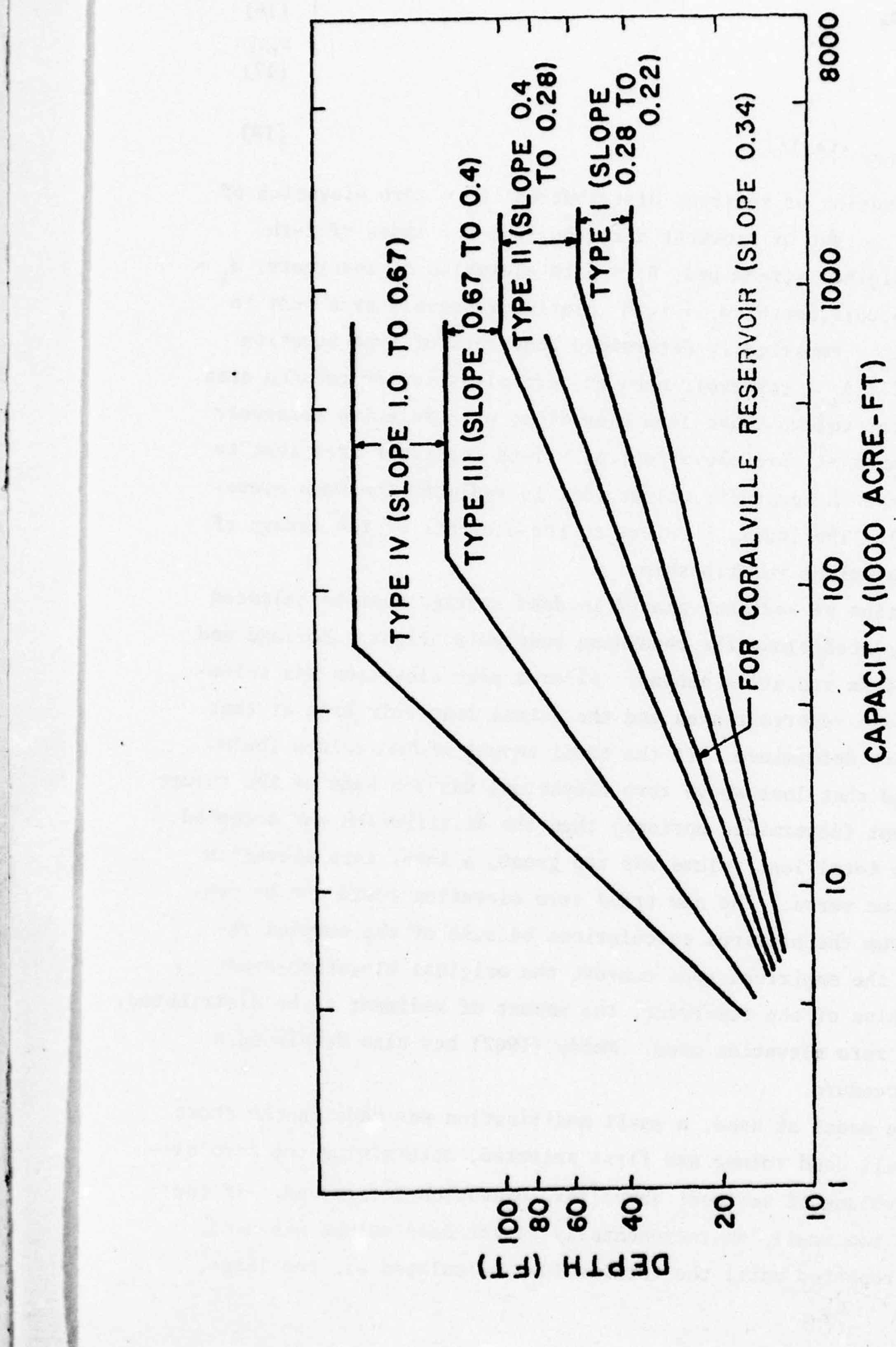

Figure 4. Classification of Coralville Reservoir by the Depth Versus Capacity Relationship

$$d_i = (E_i - E_z)/H \tag{15}$$

$$p_i = c_1 d_i^{c_2}(1 - d_i)^{c_3} \tag{16}$$

$$a_i = p_i(A_z/p_z) \tag{17}$$

$$v_i = (E_{i+1} - E_i)(a_{i+1} + a_i)/2 \tag{18}$$

where E_T = top elevation of sediment distribution; E_z = zero elevation of the reservoir; H = height of sediment distribution; i = index of i-th elevation above original stream bed; E_i = i-th elevation of reservoir; d_i = i-th relative reservoir depth; p_i = i-th relative reservoir area lost to sediment; c_1, c_2, c_3 = empirically determined constants of type equation (after Moody; 1962); A_z = reservoir area at zero elevation or reduced area for reduced sediment volume above zero elevation; p_z = relative reservoir area lost to sediment at zero elevation; a_i = i-th reservoir area lost to sediment; and v_i = i-th reservoir volume lost to sediment (between elevations E_i and E_{i+1}). The index, i refers to the elements of the arrays of the elevation-area-volume relationship.

The portion of sediment placed in dead storage must be balanced with the portion placed along the remaining reservoir height. Borland and Miller (1960) used an iterative scheme. First a zero elevation was selected and the relative reservoir area and the actual reservoir area at that zero elevation were determined. If the total amount of lost volume (below zero elevation and that lost above zero elevation) was the same as the volume of trapped sediment (determined apriori) then the distribution was accepted. Generally, if the total lost volume was too great, a lower zero elevation was chosen and vice versa. The new trial zero elevation could not be predicted exactly from the previous calculations because of the complex relationship among the empirical type curves, the original elevation-area-volume relationships of the reservoir, the amount of sediment to be distributed, and the previous zero elevation used. Moody (1962) has also developed a non-iterative procedure.

For the model at hand, a small modification was made in the above procedure. A small dead volume was first selected, determining the zero elevation, and the volume of sediment above zero elevation determined. If the total volume was too small, an incrementally larger dead volume was used. The process was repeated until the total volume calculated was too large.

Then the area of the sediment at zero elevation was reduced (reducing the amount stored above zero elevation) until the total volume stored was correct. In effect, this means that in some instances, the sediment does not slope all the way to the dam face but intersects the dam face horizontally. It is thus possible to use a predictor-corrector equation to determine the distribution.

D. Differential Settling

After the overall distribution of sediment in dead storage and along the remaining reservoir height is accomplished as just outlined, the proportions of sediment between successive indexed elevations that belong to different sediment zones (clay, silt, sand) must be determined. As an aid to determining these fractions, z_j is defined as the elevation of the top of sediment zone j and it corresponds to $\bar{v}_j = \sum_{m=1}^{j} X_m \cdot E$ on the E_i vs v_i array, where X_j is the fraction of incoming sediment that is sediment component j (j = 1 clay, 2 silt, 3 sand). It is determined by interpolation with $\bar{v}_j$ between appropriate values of v_i to obtain z_j between appropriate values of E_i. Note that $z_1 \leq z_2 \leq z_3$ and $z_3 = E_T$ [see Eq. (14)]. There are six general cases to consider in determining $X_{j,i}$ = fraction of sediment volume between indexed elevations E_i and E_{i+1} that is sediment component j.

Case I:

$$E_i < E_{i+1} \leq z_1$$

$$X_{1,i} = 1; X_{2,i} = 0; X_{3,i} = 0 ; \tag{19a}$$

$$z_1 \leq E_i < E_{i+1} \leq z_2$$

$$X_{1,i} = 0; X_{2,i} = 1; X_{3,i} = 0; \tag{19b}$$

$$z_2 \leq E_i < z_3$$

$$X_{1,i} = 0; X_{2,i} = 0; X_{3,i} = 1 \tag{19c}$$

Case II:

$$E_i < z_1 < E_{i+1} \le z_2$$

$$X_{1,i} = (z_1 - E_i)/(E_{i+1} - E_i);\ X_{2,i} = (E_{i+1} - z_1)/(E_{i+1} - E_i);$$
$$X_{3,i} = 0 \tag{20}$$

Case III:

$$E_i < z_1 \le z_2 < E_{i+1} \le z_3$$

$$X_{1,i} = (z_1 - E_i)/(E_{i+1} - E_i);\ X_{2,i} = (z_2 - z_1)/(E_{i+1} - E_i);$$
$$X_{3,i} = (E_{i+1} - z_2)/(E_{i+1} - E_i) \tag{21}$$

Case IV:

$$z_i \le E_i < z_2 < E_{i+1} \le z_3$$

$$X_{1,i} = 0;\ X_{2,i} = (z_2 - E_i)/(E_{i+1} - E_i);\ X_{3,i} = (E_{i+1} - z_2)/$$
$$(E_{i+1} - E_i) \tag{22}$$

Case V:

$$E_i < z_1 \le z_2 \le z_3 < E_{i+1}$$

$$X_{1,i} = (z_1 - E_i)/(z_3 - E_i);\ X_{2,i} = (z_2 - z_1)/(z_3 - E_i);\ X_{3,i} =$$

$$(z_3 - z_2)/(z_3 - E_i) \tag{23}$$

Case VI:

$$z_1 \le E_i < z_2 \le z_3 < E_{i+1}$$

$$x_{1,i} = 0;\ X_{2,i} = (z_2 - E_i)/(z_3 - E_i);\ X_{3,i} = (z_3 - z_2)/(z_3 - E_i) \tag{24}$$

E. Sediment Compaction

The density of aged sediment components used in compaction depends upon the age, composition, sizes, condition of submergence or non-

submergence, etc. Lane and Koelzer (1943) have proposed the following equation for compaction of sediment:

$$\gamma_m = [(\gamma_1 + K_1 \log_{10} T)P_1 + (\gamma_2 + K_2 \log_{10} T)P_2 + (\gamma_3 + K_3 \log_{10} T)\ P_3] \tag{25}$$

where γ_m = mean specific (dry) weight after time T, lb/ft^3; γ_i = mean specific weight of sediment component i, lb/ft^3 (1 = clay, 2 = silt, 3 = sand); K_i = compaction coefficient of component i, lb/ft^3; P_i = fraction of sediment in each soil class (component i); and T = time in years.

In the distribution of sediment, one may define three zones. Zone one is predominantly clay, zone two is predominantly silt and zone three is predominantly sand. For each distribution of sediment in each time period, the zones may be different in location. In each zone there is some fraction of sediment components other than the predominant component due to incomplete separation of the sediment components during settling. In addition, two submergence zones are defined: submerged and occasionally unsubmerged (or subject to normal reservoir drawdown). Thus, a sediment portion may be classified in two different ways with a total of 6 different classifications. Each of these classifications will then be represented by a particular density which will depend on the relative amounts of the sediment components in that zone, the condition of submergence, the specific weights of the components and the compaction coefficients of the components under different submergence conditions:

$$\psi_{j,k}(T) = \sum_{i=1}^{3} [\gamma_{i,k} + K_{i,k} \log_{10} T]\ P_{i,j} \tag{26}$$

where $\psi_{j,k}(T)$ = mean specific weight after time T in sediment zone j and submergence zone k (1 = below the water surface, 2 = above the water surface); $\gamma_{i,k}$ = specific weight of sediment component i in submergence zone k; $K_{i,k}$ = compaction coefficient of component i in submergence zone k; and $P_{i,j}$ = fraction of sediment zone j that is component i.

The development of eq.(26) proceeds from eq. (25) by considering sediment portions that are in a particular sediment zone and in a particular submergence zone.

One further modification of eq. (26) is necessary to account for the length of the time period used. When the sediment distribution and compaction calculations are performed other than every year, adjustment must be made for the time, T, in eq. (26). The age of sediment is taken as all past time that the sediment had been deposited up to the middle of the current time period. For example, if the time period used is 104 weeks, and the current calculations are in the fourth time period, then the oldest sediment is taken as 3(104) + 52 = 364 weeks = 7 years. So eq. (26) becomes:

$$\psi_{j,k}(T) = \sum_{i=1}^{3} [\gamma_{i,k} + K_{i,k} \log_{10} Y] P_{i,j} \tag{27}$$

where T = number of the time period and

$$Y = N/N_y \cdot (T - .5). \tag{28}$$

The overall specific weight of the sediment used in eq. (3) is as follows:

$$\psi(T) = \sum_{j=1}^{3} \psi_{j,1}(T) X_j \tag{29}$$

where $\psi(T)$ = the overall specific weight of the sediment at time period T; and X_j = fraction of incoming sediment that is sediment component j.

After the sediment is distributed along the reservoir height and after the various zone assignments are made based on predominant type of material and degree of submergence, the sediment is compacted. All older sediment distributions from previous time periods, their zone assignments and their ages are sufficient information to compact all sediment portions with respect to age, material, size of sediment, degree of submergence and position in the reservoir. In the following treatment, all symbols are retained as previously defined with the addition (where not already present) of the time variable, T. Thus, for example, $X_{j,i}(T)$ is fraction of sediment volume between indexed elevations E_i and E_{i+1} that is sediment component j in time period number T and $v_i(T)$ is i-th reservoir volume lost to sediment in time period number T. The compacted volume at time period T of sediment [which arrived earlier (say at time period number N) between elevations E_i and E_{i+1}, $v_i(N)$] is $v_i^N(T)$:

$$v_i^N(T) = \sum_{j=1}^{3} v_i(N)\, X_{j,i}(T)\, \psi_{j,k}(1)/\psi_{j,k}(T-N+1) \tag{30}$$

where k = 1 for submerged and 2 for occasionally submerged sediments. The accumulated total compacted sediment at time period number T resulting from all earlier inflows between elevations E_i and E_{i+1} is $v_i'(T)$:

$$v_i'(T) = \sum_{N=1}^{T} v_i^N(T) = \sum_{N=1}^{T} \sum_{j=1}^{3} v_i(N)\ X_{j,i}(N)\ \psi_{j,k}(1)/\psi_{j,k}(T-N+1) \quad (31)$$

F. Correction to Zero Elevation for Compaction

After calculation of the accumulation and compaction of sediment, corrections to the zero elevation for compaction of sediment must be made. Because of the uncertainties in the above model of sediment distribution as to exactly what takes place near the zero elevation, the following scheme was selected as a reasonable approximation of the change in the zero elevation due to compaction. After compaction of all sediment components in all zones of differing densities, the total dead volume is taken as the compacted amounts corresponding to those that were deposited in dead volume in all time periods before compaction. The new dead volume and zero elevation are computed as follows:

$$DV(T) = \sum_{i=1}^{k2-1} v_i'(T) + \frac{E_z - E_{k2}}{E_{k2+1} - E_{k2}} (\Delta V_{k2+1} - \Delta V_{k2}) \frac{v_{k2}'(T)}{\sum_{N=1}^{T} v_{k2}(N)} \quad (32)$$

where k2 = index of indexed elevation just below E_z before compaction. After the compacted dead volume is calculated in Eq. (32), the new zero elevation is interpolated from the original elevation-area-volume relationship (E_i, ΔA_i, ΔV_i) with DV(T) between ΔV_i and ΔV_{i+1} to determine E_z between E_i and E_{i+1}.

G. Sediment Slump Correction due to Compaction at Zero Elevation

Sometimes the compaction of sediment at the zero elevation may cause an anomaly in the reservoir surface area in the immediate neighborhood of the zero elevation. The anomaly occurs in the form of a reverse slope at the sediment surface. In practice when such a situation occurs the sediment slumps to a natural slope. The occurrence of this phenomenon is checked and, when necessary, the sediment volumes in the vicinity of the zero elevation are readjusted over the next upper few elevations. Let E_{k3} be the

indexed elevation just below the new zero elevation after compaction and k3 is the index of this elevation. Compacted sediment volumes between E_{k3} and E_{k2} are redistributed in proportion to the available reservoir volumes between the relevant indices; this guarantees that reverse slopes will not exist.

$$S = \sum_{i=1}^{k2} v'_i(T) - DV(T) \tag{33}$$

$$R = AV_{k2+1} - DV(T) \tag{34}$$

$$v'_{k3}(T) = [AV_{k3+1} - DV(T)]\,\frac{S}{R} + DV(T) - AV_{k3} \tag{35}$$

$$v'_i(T) = (AV_{i+1} - AV_i)\,\frac{S}{R};\; i = k3+1,\, k3+2, \ldots, k2 \tag{36}$$

$$A_{k3+1} = [AV_{k3+1} - AV_{k3} - v'_{k3}(T)]/(E_{k3+1} - E'_z) \tag{37}$$

$$A_i = [AV_i - AV_{i-1} - v'_{i-1}(T)]/(E_i - E_{i-1});\; i = k3+2,\, k3+3, \ldots, k2 \tag{38}$$

Sediment volumes computed by eqs. (35) and (36) are used to recompute reservoir surface areas given by eqs. (37) and (38). These reservoir areas are checked for consistency: i.e., the area at each indexed elevation must be larger than that at or immediately lower indexed elevation. If not, sediment volumes are redistributed up to the next higher elevation by incrementing k2; sediment volumes and reservoir areas are again recomputed using eqs. (33) through (38) with k2 = k2+1 and consistency in areas is checked again. This process is continued until consistency is achieved.

H. Adjustment of Elevation-Area-Volume after Sedimentation

After the losses in volume are calculated, corrections to the elevation-area-volume relationship are made. Adjusted reservoir volumes are calculated by subtracting the compacted sediment volumes from the original reservoir volumes.

$$V_i = AV_i - \sum_{\ell=1}^{i-1} v'_\ell(T) \tag{39}$$

Note:

$$\sum_{\ell=1}^{i-1} v'_{\ell}(T) = AV_i, \; E_i \leq E_{k3} \tag{40}$$

After the adjusted reservoir volumes are obtained by eq. (39), the average reservoir surface areas are calculated:

$$A'_i = 0, \; i \leq k3 \tag{41}$$

$$A'_i = (V_i - V_{i-1})/(E_i - E_{i-1}) \tag{42}$$

where A'_i = average reservoir area between indexed elevations E_{i-1} and E_i. Equations (41) and (42) are simple prismoidal equations. At this point, the average reservoir areas as computed by eq. (42) are checked for consistency, i.e., the average area between indexed elevations must be greater than that at the immediately lower set of indexed elevations. Inconsistency may occur due to slump at sediment zone interfaces.

I. <u>Correction for Slump at Sediment Zone Interfaces</u>

Differential compaction at sediment zone interfaces may cause reverse slopes, i.e., average reservoir surface areas between lower elevations become larger than those at higher elevations. When such anomalies are found, sediments are redistributed in the neighboring elevations in proportion to the available reservoir volumes between the relevant indices.

$$S = v'_{i-2}(T) + v'_{i-1}(T) \tag{43}$$

$$R = AV_i - AV_{i-2} \tag{44}$$

$$v'_{i-2}(T) = (AV_{i-1} - AV_{i-2}) \frac{S}{R} \tag{45}$$

$$v'_{i-1}(T) = (AV_i - AV_{i-1}) \frac{S}{R} \tag{46}$$

When an anomaly occurs at two or more consecutive elevation indices, eqs. (43) through (46) are extended for redistribution of sediment volumes between relevant additional elevation indices in the neighborhood. After the corrections indicated by eqs. (43) through (46) are made, where necessary, corrected sediment volumes given by eqs. (45) and (46) are used to recompute reservoir volumes and average surface areas by eqs. (39) through (42). Finally, the average reservoir surface areas are used to compute the index areas at each indexed elevation.

$$A_i = 0;\ i \le k3 \tag{47}$$

$$A_{k3+1} = \frac{E_{k3+1} - E'_z}{E_{k3+2} - E'_z}(A'_{k3+2} - A'_{k3+1}) + A'_{k3+1} \tag{48}$$

$$A_i = \frac{E_i - E_{i-1}}{E_{i+1} - E_{i-1}}(A'_{i+1} - A'_i) + A'_i;\ i=k3+2,\ k3+3,\ldots,M \tag{49}$$

where M is the topmost index for elevation-area-volume for the reservoir.

$$A_M = 2A'_M - A_{M-1} \tag{50}$$

$$A'_z = 2A'_{k3+1} - A_{k3+1} \tag{51}$$

Equations (47) through (51) are based upon linear interpolation by using the average area A'_i between indexed elevations E_{i-1} and E_i to compute the area A_i at each indexed elevation E_i.

J. Sediment Redistribution to Conform with the Accumulated Distribution Over All Ages

The redistribution of sediment to account for the slumping at the zero elevation and at the interfaces of the sediment zones disrupts the conformity between the quantities of compacted sediment of each age, $\sum_{N=1}^{T} v_i^N(T)$ and the accumulated (over all ages) sediment quantities at each elevation, $v'_i(T)$. For agreement of the two quantities, the compacted sediment of each age, $v_i^N(T)$ is redistributed. This is necessary so that during subsequent time intervals, sediment quantities are compacted by relevant specific weights, representative of proper material, age, and submergence. This redistribution of $v_i^N(T)$ is accomplished as follows:

a) If $\sum_{N=1}^{T} v_i^N(T) \ge v'_i(T)$, then $v_i^N(T)$ for each N is reduced by multiplication times the ratio $v'_i(T)/\sum_{N=1}^{T} v_i^N(T)$. For each

N, a "credit account" is kept to indicate the amount by which the $v_i^N(T)$, i=1,...,M were reduced. The credit account contains the excess amounts for each N, accumulated over i=1,...,M to be redistributed among the remaining $v_i^N(T)$.

b) For each i such that $\sum_{N=1}^{T} v_i^N(T) < v_i'(T)$, the $v_i^N(T)$ are increased progressively. First, the $v_i^N(T)$ are multiplied by the ratio $v_i'(T)/\sum_{N=1}^{T} v_i^N(T)$ and the increase for each N is subtracted from the credit account. If the increase for a given N exceeds the amount in the credit account, then it is limited to the amount left in the credit account, resulting in a zero balance in the credit account for that N. If the credit account is not empty for some N, then the second increase of $v_i^N(T)$ is made by increasing $v_i^N(T)$ by whatever is left in the credit account but not allowing $\sum_{N=1}^{T} v_i^N(T)$ to exceed $v_i'(T)$. Subtraction of transferred amounts is made from the credit account. The second increase starts with the latest sediment and proceeds to the oldest. Whenever the credit account becomes empty for all N, the redistribution stops. If after the second increase, the credit account is still not empty for some N, then a third increase is made. Filling in of $v_i^N(T)$ is made so that $\sum_{N=1}^{T} v_i^N(T) = v_i'(T)$ for ages (N) not previously increased in the first two increases. These are later ages where the reservoir had filled previously and no new sediments were deposited at low elevations. The redistribution can then be likened to filling of old dead storage where cracks opened up due to compaction.

c) Step b is repeated for each index, i=1,...,M in order of increasing i.

Theoretically, continuity is maintained and after the redistribution (which is admittedly arbitrary) $\sum_{N=1}^{T} v_i^N(T) = v_i'(T)$, i=1,...,M. Round-off errors in the computer make it necessary to place checks on remaining sediment to be distributed so that after an arbitrarily small amount is left, redistribution ceases. Otherwise, small negative amounts (zeros theoretically) are being transferred. These negative amounts have potential for error propogation in subsegment compactions (larger T).

Continuity is theoretically maintained in another way also. For each N, the total amount at that age has not changed; thus $\sum_{i=1}^{M} v_i^N(T)$ is the same after the redistribution as it was before the redistribution. Since the redistribution results in a filling in of lower elevations with same-age sediment from higher elevations for each age (layer) of sediments, the fraction between each set of indexed elevations of each age that is component j has changed $[X_{j,i}(N)]$. By keeping track, during the compaction calculations, of sediment in each zone as delineated by the zone elevations, z_1, z_2, and z_3, the fraction of compacted sediment of each component (volumetric basis) X'_j can be computed similar to X_j for the uncompacted sediment. The $X_{j,i}(N)$ can then be recomputed by calculating $\bar{v}_j^N = \sum_{m=1}^{j} X'_m [\sum_{i=1}^{M} v_i^N(T)]$ and interpolating on the E_i vs $v_i^N(T)$ array with $\bar{v}_j^N$ between appropriate values of $v_i^N(T)$ to obtain z'_j between appropriate values of E_i. Note again that $z'_1 \leq z'_2 \leq z'_3$. $X_{j,i}(N)$ can be recomputed now corresponding to post-compaction in time period number N by utilizing eqs. (19) through (24) with z'_j replacing z_j and $X_{j,i}(N)$ replacing $X_{j,i}$; N=1,...,T. Actually the calculations of Eqs. (19) through (24) can be made directly in terms of $\bar{v}_j^N$ and $v_i^N(N)$ instead of z'_j and E_i and is so done in the computer program.

K. Determination of Equivalent Uncompacted Sediment Volumes and Redefinition of Sediment Zones.

The uncompacted equivalent volumes for each $v_i^N(T)$, i=1,...,M; N=1,...,T are desired so that compactions at the next time period (T+1) can proceed in the same manner as illustrated in sections A through J herein for time period number T. One method that is rather straightforward is to solve eq. (30) for $v_i(N)$ by using the corrected values for $v_i^N(T)$ and $X_{j,i}(N)$. This method has the disadvantage that continuity of mass is not preserved. Sediment that was previously deposited in the occasionally submerged zone but which now has slumped into the submerged zone will continue compaction in successive time periods with wet zone coefficients in the sediment density formula and by using an initial density which it did not originally have. Since sediment slumping is minor and since techniques to keep track of original densities are extremely cumbersome and since little is known

about compaction of sediment that changes submergence zones, this procedure was adopted for the reservoir sedimentation model. Thus, the uncompacted equivalent volume, $v_i(N)$ is determined from eq. (30):

$$v_i(N) = v_i^N(T)/[\sum_{j=1}^{3} X_{j,i}(N)\ \psi_{j,k}(1)/\psi_{j,k}(T-N+1)] \tag{52}$$

The recalculation of $X_{j,i}(N)$ to again correspond to the uncompacted equivalent volumes $v_i(N)$ must also be made so they are ready for the next set of computations with uncompacted sediments in the next time period. This is done in a manner similar to that just described at the end of section J. By keeping track, during the decompaction calculations, of sediment in each zone as delineated by the zone elevations, z_1'. z_2', and z_3', the fraction of uncompacted sediment of each component (volumetric basis) X_j can be computed similar to X_j' for the compacted sediment or X_j for the uncompacted sediment preceding the current compaction-decompaction calculations. The $X_{j,i}(N)$ can then be recomputed by again calculating $\bar{v}_j^N = \sum_{m=1}^{j} X_m \cdot [\sum_{i=1}^{M} v_i(N)]$ and interpolating on the E_i vs $v_i(N)$ array with $\bar{v}_j^N$ between appropriate values of $v_i(N)$ to obtain z_j between appropriate values of E_i. Note again that $z_1 \leq z_2 \leq z_3$. $X_{j,i}(N)$ can be recomputed now corresponding to decompaction in time period number N by utilizing eqs. (19) through (24), N=1,...,T. Again, the calculations can be made directly in terms of $\bar{v}_j^N$ and $v_i(N)$ instead of z_j and E_i and are so done in the computer program.

III. COMPUTER PROGRAM FOR THE RESERVOIR SIMULATION MODEL

The scheme of computations were inplemented through a computer code written in FORTRAN IV, for use on the IBM 360/65 computer at The University of Iowa, Iowa City. The simulation procedure includes generation of sequences of time series data relating to water and sediment inflows, and pan evaporation on a weekly basis. During each interval of time (week) the water inflow is routed through the reservoir and the operation schedule is used to determine the water outflow, subject to the system constraints.

Then from the generated pan evaporation, the relevant reservoir surface area, and the evaporation coefficient, the loss of storage due to evaporation is calculated. In the present scheme other losses due to seepage, etc., are ignored. The reservoir head, corresponding to the net storage (after deducting the evaporation loss from gross storage), is taken as the height of the reservoir over which the incoming sediment is distributed.

The sedimentation submodel first estimates the quantity of sediment that will be trapped in the reservoir using the entrapment model (Section IV-B). The entrapped sediment is next distributed over the reservoir height and compacted at regular time intervals as detailed in Section II. Based on the extent of sedimentation, the reservoir profile is adjusted with regard to the elevation-area-volume relationship.

Further elaboration of the scheme of computations is furnished with brief description of the computer program, given below.

A. MAIN Program

The MAIN program reads in all the system variables, parameters and control data from the data deck. It reads in informations relating to the number of years for which the simulation is to be carried out, the periods, at the end of which the accumulated sediment is to be distributed and compacted, the reservoir inflow data, sediment characteristics for calculation of densities, sediment composition in the three assigned zones of clay, silt, and sand, fractions of incoming sediment that are components of clay, silt, and sand, the numerical designation of the type of reservoir (as per Borland's classification), original elevation-area-volume relationship of the reservoir, weekly evaporation coefficients, all the parameters and the stochastic component distributions required for the generation of the time series values for water inflow, sediment inflow, and evaporation, the discharging capacities of the spillway and conduit at increments of 5000 acre-ft ($6.17 \cdot 10^6 m^3$) of storage, and the corresponding reservoir elevations, and the existing operation plan defined in terms of pool elevation. The MAIN Program also computes the densities of sediments in the six sediment zones, divided on the basis of sediment composition and submergence, and the average overall density of the incoming sediment. All the relevant parameters are initialized.

B. Subroutine CALCMA

The MAIN Program then calls the subroutine CALCMA which calculates the weekly variances of the independent stochastic component for the water inflow time series model. These values will be used in the synthetic generation of water inflow data. Such calculations are not required for sediment and evaporation series since for these no detailed auto-covariance models were used.

C. Subroutine INPUTS

Next the MAIN Program calls the subroutine INPUTS. Under its control synthetic sequences of data for water inflow, sediment inflow, and evaporation are generated. Each discrete (weekly) sequence is of length equal to the period of reservoir simulation. If, in the analysis, historical data is used instead of one or more of the series, the subroutine accordingly generates the data for the required process or processes only. The computations in INPUTS are made in the following steps:

a) Note the order of the selected Markov model of dependence if for the concerned series a Markov model was used for data generation.

b) Generate a random number from the uniform distribution over the interval, (0,1). For data generation purposes, the random number from the uniform distribution was generated as follows:

$$r_\ell = \mathrm{Dec}[\pi + r_{\ell-1}]^{11} \tag{53}$$

where $r_{\ell-1}$ = previous random number; r_ℓ = new random number; π = any irrational number; and Dec(·) = a function which takes only the decimal part of the argument.

c) Calculate the independent stochastic component through linear interpolation using the array of the inverse cumulative distribution as below:

$$i = \mathrm{Int}[r_\ell \cdot N] + 1 \tag{54}$$

$$\xi^* = G_i + (G_{i+1} - G_i)(r_\ell - H_i)/(H_{i+1} - H_i) \tag{55}$$

where N = number of values in arrays G and H; i = index of H array just smaller than or equal to r_ℓ, Int(·) = a function which takes only the whole (integer) part of the argument; H(·) = array of N equally spaced number

from 0 to 1 inclusive; $G(\cdot)$ = array of the inverse cumulative distribution for the independent stochastic component; and ξ^* = the independent stochastic component calculated through linear interpolation.

d) Calculate the dependent stochastic component if a Markov Model for the time series is used.

e) Add periodicities and/or trends over the year in the selected Markov model dependence structure if step d is relevant.

f) Add periodicities and/or trends over the year in the mean and standard deviation.

g) Check the generated output for negative values (should be rare) and if negative, return to step b. Multiply the final generated values for water and sediment inflows by 1/1.6127 and 1.35 respectively so that the mean values for 10 years agree with the historical values. The factors 1/1.6127 and 1.35 are applicable to the Coralville reservoir only.

h) Assign the value of the stochastic component to the location of the previous stochastic component; assign the previous value to the location of the second previous value, etc.

D. Subroutine OPERAT

Next the MAIN Program calls subroutine OPERAT which, under its control, determines the outflow from the reservoir during the week, considering the inflow, operation plan, and the system constraints. The average reservoir storage, elevation and surface area during the week are calculated for subsequent use in subroutine EVAPCO and SEDCOM, which are called from this subroutine.

E. Subroutine EVAPCO

Subroutine EVAPCO is then called to compute the loss of reservoir storage from the average storage, the generated pan evaporation, and the evaporation coefficient for the week, and returns the control to OPERAT, where the net storage and the corresponding head are calculated.

F. Subroutine SEDCOM

Subroutine SEDCOM, which is the vital segment of the simulation scheme, is called from subroutine OPERAT. The sediment accumulation, deposition, and compaction is computed in subroutine SEDCOM. The subroutine

is designed to be used, in general, for any time increment other than a week, for any length of time, and for any desired correction period for distribution and compaction. For illustration of the model, the calculations for accumulation proceed every week and the calculations for the distribution and compaction are made every year. The periods may easily be changed by changing the basic parameters used in the subroutine. The calculations in the subroutine proceed in the following steps:

a) Decide if the current time increment (week) is to be an accumulation increment only or an accumulation, distribution and compaction increment.

b) Accumulate water inflow (acre-ft), sediment inflow (tons), reservoir volume (acre-ft), and head (ft) in the reservoir.

c) If the time increment is for accumulation, distribution and compaction of sediment, index the number of the correction period.

d) Determine the average head in the reservoir.

e) Estimate the total sediment trapped using the regression model.

f) Calculate the age of the oldest sediment and if it is smaller than one year, make it equal to one year (which gives no compaction)

g) Determine the densities of the aged sediment components.

h) If the trapped sediment is less than 10 tons, then skip following computations and add this small amount to that trapped during the succeeding period. Convert the trapped sediment from tons into acre-ft.

i) Calculate the relative sediment areas at each of the indexed elevations up to an index value just above the average reservoir elevation during the current period. Distribute the sediment along this reservoir height. This is done in the following steps:

(i) Determine the current zero elevation.

(ii) Interpolate and determine the new zero elevation corresponding to the addition of the given increment of sediment volume to the dead storage (a value of 3% is used here; other values can be used). Calculate the actual reservoir area and volume at this elevation.

(iii) Calculate the relative sediment areas at the new zero elevation found in (ii) and other elevations above zero elevation up to the average reservoir water surface.

(iv) Distribute the sediment areas along the reservoir height, using the actual reservoir area found in (ii) and the relative sediment areas found in (iii).

(v) Sediment volumes at each elevation are calculated using average end-area formulae, added to the dead storage, and accumulated.

(vi) Next, the incremental sediment volume is added to the dead storage and steps (ii) through (v) are repeated until the total volume of distributed sediment found in (v) is equal to the predetermined sediment volume trapped during the time period.

j) Separate the distributed sediment into 3 zones - clay, silt and sand, and interpolate the index values demarcating the zones.

k) Compact the sediment at each elevation with respect to the densities as functions of material, age, and submergence.

l) Correct the zero elevation for compaction of sediment.

m) Adjust the elevation-area-volume relation for the reservoir considering the extent of sedimentation. Compaction of sediment at the zero elevation and at sediment zone interfaces may give rise to anamolies when reservoir surface areas at higher elevations are smaller than those at lower elevations. Check for this anamoly and, if it occurs, remove by redistributing the sediment in the lower elevations.

n) Redistribute the compacted sediment of each age to agree with accumulated (over all ages) sediment distribution. This is necessitated by the adjustment in the step m above.

o) Write out the outputs - distribution of compacted sediment of all ages, the adjusted elevation-area-volume relation and the new zero elevation for each correction period.

p) Calculate the "equivalent" uncompacted sediment of each age from the redistributed compacted sediment.

q) Reinitialize all the relevant parameters for use in the next correction period.

r) Steps a through q are repeated until accumulated correction periods equal the total time period of simulation.

IV. INPUTS FOR RESERVOIR SIMULATION

The inputs to the sumulation model are water inflow, sediment inflow and evaporation. The simulation model is operated at discrete time intervals and inputs correspond to the same intervals of time. Although in the example problem the time interval is a week, the model can be operated for any other desired interval. Each input, generated or historical, has to be of length equivalent to the operation horizon of simulation. To generate such inputs, time series models are constructed and described in this section. The models are specific to the Coralville reservoir problem which is chosen for the demonstration of the model. These models are built by utilizing the recorded data to the extent available. A brief description of the Coralville reservoir preceeds the development of the mathematical models for generation of water inflow, sediment inflow and evaporation series.

A. General Description of the Coralville Reservoir

The watershed of the Iowa river above the Coralville dam (figure 5) has the general pattern of a willow leaf, typical of eastern Iowa streams; it is long and narrow and curves from the northwest to the southeast. The river, from its headwaters to the dam site, is about 280 miles long (450 km). The drainage area above the dam site is 3115 square miles (8064.3 sq km) and the average width of the catchment area is 18.5 miles (29.8 km). The upper 1300 square miles (3366 sq. km) of the watershed lies on glacial till of Wisconsin age with the topography characterized by a quite flat plain in which drainage is relatively poor. Such a plain contributes relatively little to the sediment load of the Iowa river. The lower portion of this watershed lies upon older glacial drift and loess deposits; the surface slopes more and is more susceptible to erosion. Hence, this portion of the watershed contributes the major part of the sediment load to the river. The average precipitation for this area is about 32 inches (813 mm) annually.

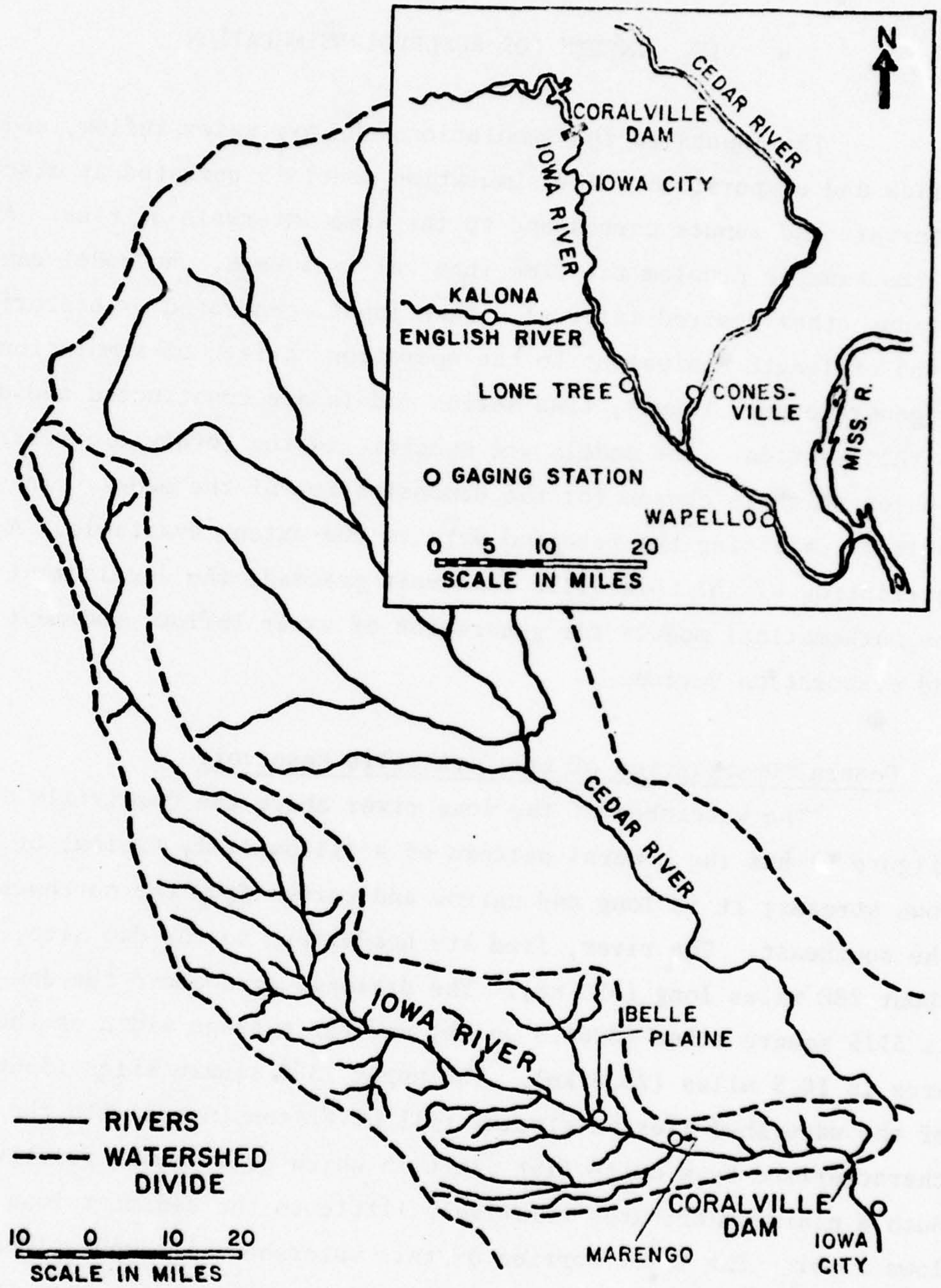

Figure 5. Schematic Map of Iowa River Basin
(1 mile = 1.6 km.)

The Coralville reservoir is located at the Turkey Creek site, 5 miles (8 km) upstream from Iowa City in Johnson County, Iowa. The dam rises approximately 110 feet (33.53 m) in height at its maximum point and is 1400 feet (426.7 m) long. The dam crest is at EL 743.0 feet (226.47 m) m.s.l. The reservoir went into operation in the year 1958. The details of capacity and reservoir surface area versus elevation are given in figure 6 (table A1 in appendix A). The pool is 17.4 miles (28 km) long at EL 670.0 feet (204.22 m) m.s.l., 21.7 miles (34.92 km) long at EL 680.0 feet (207.26 m) and at the full flood pool elevation of EL 712.0 feet (217.02 m) m.s.l., the pool is 35.0 miles (56.3 km) long.

Normally, flows into the reservoir are controlled by means of a 23 foot (7.01 m) circular, concrete conduit 350 feet (106.68 m) long, with the floor at EL 646.0 feet (196.9 m). It is regulated by three 8.33 feet (2.54 m) by 20 feet (6.1 m) vertical lift gates. Maximum discharge through the conduit varies from about 7000 cfs (198.2 m^3/sec) with a 670.0 foot (204.22 m) m.s.l. pool to 20,000 cfs (566.4 m^3/sec) at the full flood pool level of 712.0 feet (217.02 m) m.s.l.; see figure 7. A concrete, ogee-crest, overflow spillway exists to convey water from the reservoir under the occurrence of more rare types of floods, to keep the dam from being overtopped. The spillway crest is at EL 712.0 feet (217.02 m) m.s.l., and is 500 feet (152.4 m) long. No water has been discharged through the spillway to date, although in 1969 the maximum flood elevation was nearly reached (711.85 feet or 216.97 m m.s.l.). The spillway rating curve is given as figure 8.

B. Input-Models

Reservoir Inflow. The approach adopted in this study for the generation of weekly reservoir inflows involves the construction of detailed autocovariance models for the residuals obtained after removal of seasonal (within-the-year) periodicities in the weekly mean and standard deviation (Croley, 1976). The autocovariance models tested were Markov models of various lags which preserve seasonal variations (within-the-year non-stationarity) in the autocorrelation coefficients. The best fit model was determined to be a first-order Markov model with 52-week periodicities in the mean, standard deviation, and first-order serial correlation coefficient. Inflow data is given in table D1 in appendix D.

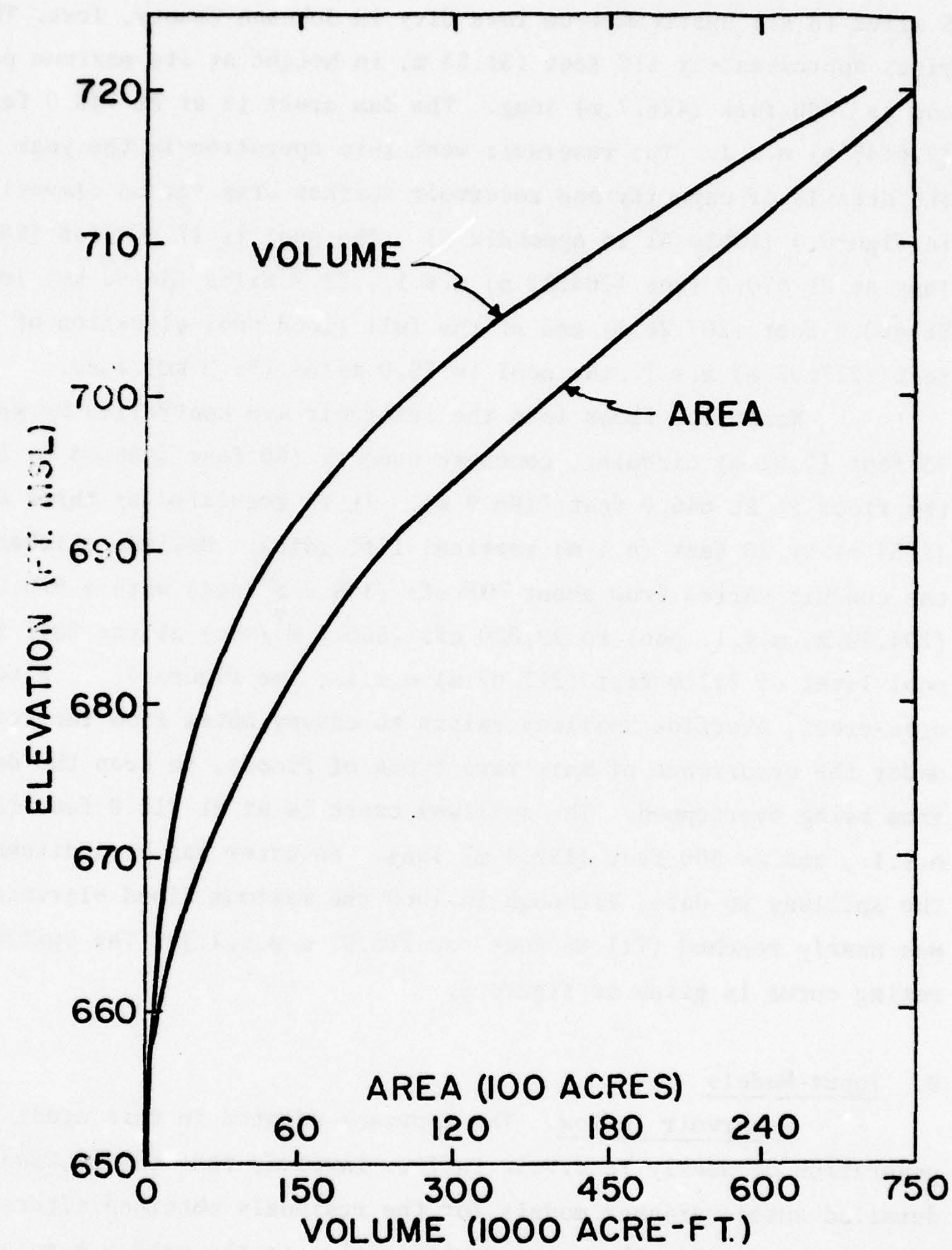

Figure 6. Area-Capacity Curves (1958), Coralville Reservoir

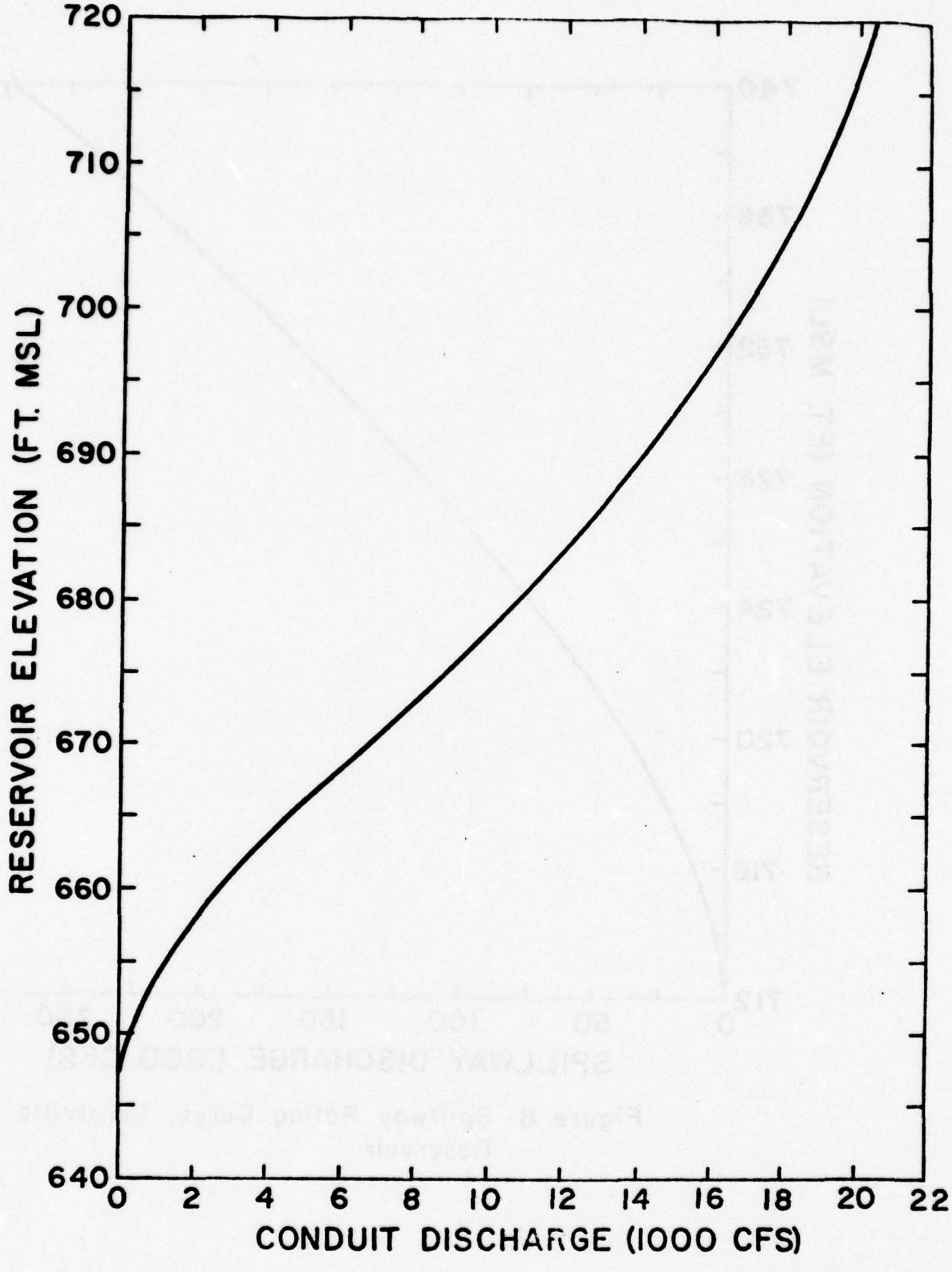

Figure 7. Conduit Rating Curve, Coralville Reservoir

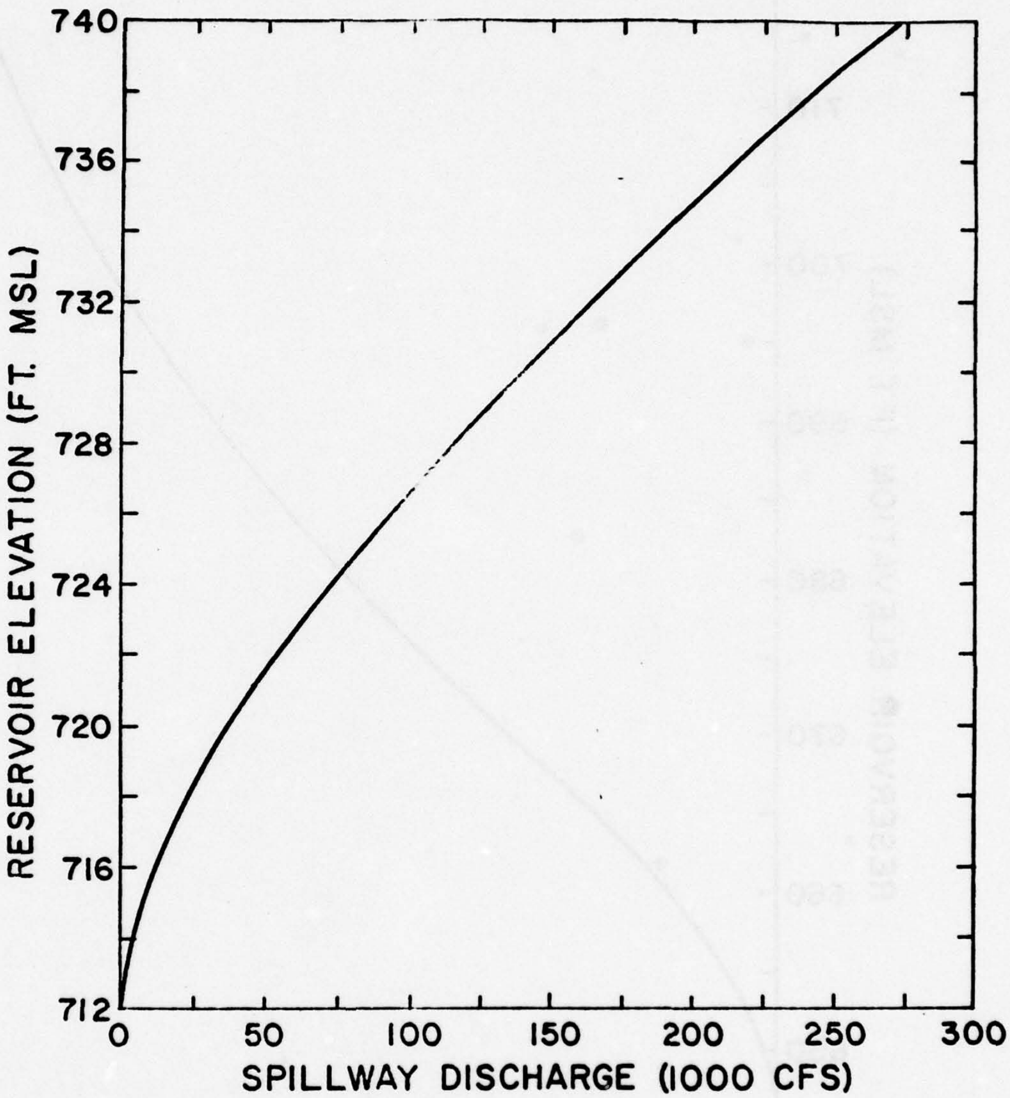

Figure 8. Spillway Rating Curve, Coralville Reservoir

$$I_i = \left[\left(\frac{I_{i-1} - \mu_{i-1}}{\sigma_{i-1}}\right) \rho_{i-1} + \sqrt{1 - \rho_{i-1}^2}\,\xi_i \right] \sigma_i + \mu_i \tag{56}$$

Where I_i = reservoir inflow in week i in acre-feet/week (1234 m^3/week); μ_i = weekly mean for week i in acre-feet/week (1234 m^3/week) as listed in table A2 in appendix A; σ_i = weekly standard deviation for week i in acre-feet/week (1234 m^3/week) as given in table A3 appendix A) ; ρ_i = correlation coefficient between the standardized values of week i-1 with week i as listed in table A4 in appendix A; ξ_i = independent stochastic component for week i which is distributed as tabulated in table A5 in appendix A. The weekly means were estimated from the data and multiplied by 1.115,which represents an adjustment factor to include runoff contributions between Marengo and the dam site. This factor was taken as the ratio of watershed area above the dam site to that above Marengo.

Sediment Inflow. A detailed autocovariance model similar to that used for reservoir inflows could not be fitted for sediment inflows because of the paucity of continuous data (see table D2 in appendix D). Utilizing the sediment inflow data to the extent available, a linear regression equation was fitted between sediment and water inflows. The emperical distribution of the residuals was calculated and used for the generation of the sediment inflow time series as follows:

$$IS_i = \left[\left(C_1 + C_2 \left(\frac{I_i - \mu_i}{\sigma_i}\right)\right) \sigma_{s_i} + \mu_{s_i} + \xi_{s_i} \right] K \tag{57}$$

Where IS_i = sediment inflow in week i in tons/week (907.18 kg/week); μ_{s_i} and σ_{s_i} = weekly mean and standard deviation, respectively, of sediment inflow for week i in tons/week (907.18 kg/week) (tables A6 and A7 in appendix A); I_i = reservoir inflow in week i in acre-feet/week (1234 m^3/week); C_1 and C_2 are regression constants (0.0547 and 0.3074 respectively); ξ_{s_i} = independent stochastic component of sediment inflow for week i, with its empirical distribution given in table A8 in appendix A; K = an adjustment factor, 1.35, derived from sediment studies such that the predicted reservoir sedimentation agrees with that observed during the 1958-68 decade.

Sediment Entrapment. As the sediment flows into the reservoir, only a part of it is trapped depending upon the period of the year, the size and shape of the reservoir, the inflowing amounts of water and sediment, the outflow from the reservoir, the reservoir volume during the

time period under consideration, the detention time of the reservoir, the character of the sediment, the outlet characteristics of the reservoir, and its operation. In this study the outlet characteristics of the reservoir are considered as unchanging throughout the operation life and changes in the size and shape of the reservoir and character of the incoming sediment are taken as insignificant with regard to influences on sediment entrapment. Regression analysis allowed elimination of many factors; sediment inflow, reservoir outflow, and reservoir volume were indicated as being significant influences on sediment entrapment for the Coralville Reservoir.

Sediment entrapment in the reservoir is estimated herein with a linear regression model based upon the available historical data for the Coralville Reservoir:

$$St_i = C_3 + C_4\, IS_i + C_5\, d_i + C_6\, V_i \tag{58}$$

Where St_i = sediment trapped in week i in tons/week (907.18 kg/week); IS_i = sediment inflow in week i in tons/week (907.18 kg/week); d_i = release of water in acre-feet/week (1234 m^3/week); V_i = volume of water in the reservoir during week i in acre-feet/week (1234 m^3/week) and C_3, C_4, C_5 and C_6 are regression constants, whose values are 111.68, 0.988, -0.1172 and 0.0215, respectively. When sufficient data on sediment inflow is not available to allow regression analysis, Brune's (1953) method may be used for the same purpose.

<u>Evaporation</u>. There are many models in the literature for the calculation of reservoir evaporation. The drawback of these models is the amount of data required for estimates of reservoir evaporation. Without resort to simulation of other time series of wind speed and direction, relative humidity, temperature of air, temperature of water, etc., the utility of these models is very limited. In view of the complexities in real evaporation, the inherent error in all models, and the requirements of complex models, a simplified procedure was used in this study. At Iowa City [about 5 miles (8 km) from the Coralville reservoir] daily observations of pan evaporation are being made (U.S. Weather Bureau, Climatological Data). Unfortunately, the collection of data is confined only to the non-winter months (April through October), listed in table D3

in appendix D. The discontinuity of data (although data is available for sufficiently long periods of time) does not allow the construction of a detailed auto-covariance time series model for pan evaporation. However, the missing data can be estimated by making use of Adolph F. Meyer's, "Evaporation from Lakes and Reservoirs", and the Weather Bureau's, "Evaporation Maps of the U.S.".

Assuming that weekly pan evaporation is serially independent (data is insufficient to establish independence) the standardized values can be used to estimate the distribution of the independent stochastic component in the following relation

$$E_i = \mu_{e_i} + \sigma_{e_i} \xi_{e_i} \tag{59}$$

where E_i = weekly pan evaporation for week i in inches/week (254 mm/week); μe_i = weekly mean pan evaporation for week i in inches/week (254 mm/week); σe_i = weekly standard deviation of pan evaporation in inches/week (254 mm/week); and ξ_{e_i} = independent stochastic component of pan evaporation for week i. The published evaporation maps and Meyer's work were used to fill in values of the weekly means impossible to estimate from the data. The weekly mean pan evaporation shows considerable variation over the year as given in table A9 in appendix A. However, the standard deviation does not show any significant trend over the non-winter months for which data was available for estimation. Since there appear to be no readily apparent physical reasons why pan evaporation variation should be different during the winter months, the average value of 0.3805 inches/week (9.66 mm/week), (obtained over the non-winter months) was adopted for the standard deviation throughout the year. The distribution for the independent stochastic component was estimated from available data and used throughout the year (table A10 in appendix A). The weekly reservoir evaporation may be then computed by multiplying generated pan evaporation by the appropriate pan coefficient and by the reservoir area corresponding to the calculated reservoir volume of pool elevation for that week.

The pan coefficient is a periodic deterministic function for the week of the year for any particular location. The function is supposed to depend upon climatic conditions, pan type, location, and local conditions with respect to the reservoir, etc. For the period April

through October, the weekly pan coefficients are estimated from the available pan evaporation data and Meyer's "Evaporation from Lakes and Reservoirs". The weekly pan coefficients during this period (April through October) show an increasing trend with time. The trend indicates that the coefficients increase with increases in mean daily temperature. Considering this trend and the fall of temperatures beyond October (November through March) the values of the weekly pan coefficients during the rest of the period were subjectively estimated. Table A11 in appendix A contains the values of the weekly pan coefficients.

Reservoir Operation. The operation schedule used in the simulation scheme is the existing reservoir operation plan of the reservoir. The operation plan is described schematically in figure 9. This plan was formulated by the United States Army Corps of Engineers, and provides primarily flood protection to the downstream regions. Under this plan the storage is not expected to exceed the spillway crest at EL 712.00 feet (217.02 m). The plan features a flood season (15 February through 15 June) pool elevation of 670.0 feet (17000 acre-feet or $20.97 \times 10^6 m^3$, of storage); a summer (15 June through 25 September) level of 680.0 feet (50800 acre-feet of storage); a fall (25 September through 15 December) level of 683.0 feet (55700 acre-feet of storage or $68.69 \times 10^6 m^3$); and a winter (15 December through 1 February) level of 680.0 feet (207.26 m). The higher level in the fall was to provide a better habitat for migratory water fowl during the hunting season.

In the simulation scheme, the operation rule determines the outflow during each interval of time to the extent practicable in consideration of the inflow during the interval, the reservoir state at the beginning of the interval, and the desired pool level of the plan. In case the outflow is more than the combined capacities of the spillway and the conduit, the outflow is limited to the latter quantity. On the other hand, if the determined outflows is less than the required discharge over the ungated spillway, then it is constrained to that quantity.

After determining the eventual outflow that satisfies all the system constraints, the resulting reservoir state and the corresponding reservoir surface area are computed. The evaporation model estimates the quantity of water evaporated during the period considering the generated pan evaporation for the time interval, the relevant evaporation coefficient,

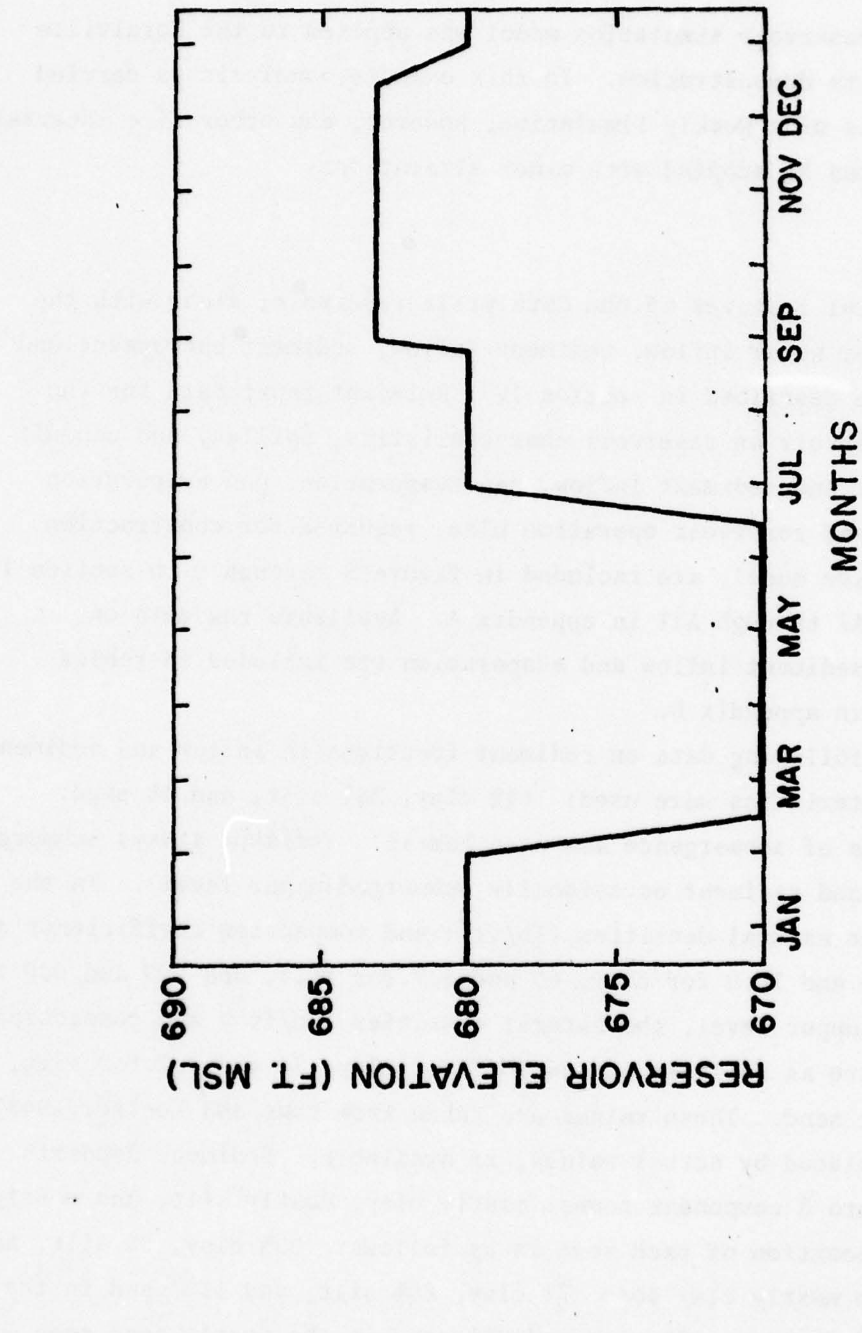

Figure 9. Current Operation Plan, Coralville Reservoir

and the reservoir surface area. By using this information the net reservoir volume after evaporation is computed.

V. APPLICATION TO THE CORALVILLE RESERVOIR

The reservoir simulation model was applied to the Coralville reservoir for its demonstration. In this example, analysis is carried out on the basis of a weekly simulation; however, any other time interval of simulation can be adopted with minor alterations.

A. Data Input

General features of the Coralville reservoir, along with the input models for water inflow, sediment inflow, sediment entrapment and evaporation are described in section IV. Relevant input data for the Coralville reservoir on reservoir characteristics, spillway and conduit dicharge, water and sediment inflow, pan evaporation, pan evaporation coefficients, and reservoir operation plan, required for construction of the simulation model, are included in figure 5 through 9 in section IV and in tables A1 through A11 in appendix A. Available raw data on water inflow, sediment inflow and evaporation are included in tables D1 through D3 in appendix D.

The following data on sediment fractions in inflow and sediment density characteristics were used: 61% clay, 38% silt, and 1% sand. Only two levels of submergence are used herein: sediment always submerged (lower level) and sediment occasionally submerged (upper level). In the lower level, the natural densities (lb/ft^3) and compaction coefficients are as follows: 30 and 16.0 for clay, 65 and 5.7 for silt, and 93 and 0.0 for sand. In the upper level, the natural densities (lb/ft^3) and compaction coefficients are as follows: 46 and 10.7 for clay, 74 and 2.7 for silt, and 93 and 0.0 for sand. These values are taken from Lane and Koelzer(1943), and can be replaced by actual values, if available. Sediment deposits are divided into 3 component zones: mostly clay, mostly silt, and mostly sand. The composition of each zone is as follows: 95% clay, 5% silt, and 0% sand in the mostly clay zone, 7% clay, 80% silt, and 13% sand in the mostly silt zone, and 0% clay, 10% silt, and 90% sand in the mostly sand zone.

The program was run with these input values for a simulation period of 10 years, 1958-1968. Adjustment for compaction and slump is made at two intervals of time: weekly and yearly, for comparison purposes. The listing of the program along with the output is given in appendix B. A list of the variables used in the computer program is given in appendix C.

B. Comparison with Actual Survey Data

The Coralville reservoir went into operation in 1958. Sediment surveys in the reservoir were made in 1964 and 1968. To check the validity of the model, a comparison is made between the adjusted reservoir elevation-area-volume relationship obtained from survey data with that computed by the simulation model. For this purpose, the historical water inflow for the period 1958-1968 (see table D1 in appendix D) were used. However, actual sediment inflow data for the same period could not be used, since such data for the whole period are not available; generated sediment inflow data are used instead.

The elevation-area-volume relationship computed by the model, along with that obtained from survey of 1958 (when the reservoir went into operation) and 1968 is given in table 1. Incremental sediment volumes deposited between different elevations given by the model after 10 years of operation (1958-68) are also compared with those obtained from 1968 survey in table 1. A note may be made here regarding the 1958 and 1968 survey data. Since cumulative reservoir capacities are given at certain contour intervals (sometimes as large as 10 ft) by the Corps of Engineers, it is necessary for comparison purposes to interpolate between indicated elevations. Such interpolation involves some uncertainty and so a spread of the survey data is used to account for this. Consideration of this spread becomes particularly significant in the case of the incremental sediment volumes, which are obtained as incremental capacities for the 1958 survey minus those for the 1968 survey between corresponding elevations. This spread in survey data is shown in the last column of table 1. Cumulative reservoir capacities and areas are plotted in figure 10. Incremental sediment volumes along with the spread of the survey data are presented in figure 11. A comparison of model results and survey data in table 1 and figures 10 and 11 shows very good agreement, except at higher levations. It is observed from table 1 that model results show no sediment deposition above elevation 678.00, while survey data shows sediment deposition (or

Table 1

Comparison of Capacities, Areas and Sediment Volumes for the Coralville Reservoir

Elevation (Ft.MSL)	Cumulative Capacities (acre-ft) 1958 Survey	1968 Survey	1968 Computed $\frac{\text{weekly correction}}{\text{yearly correction}}$	Cumulative Areas (acres) 1958 Survey	1968 Survey	1968 Computed $\frac{\text{weekly correction}}{\text{yearly correction}}$	Sediment Volumes (Incremental) (acre-ft) 1968 Computed $\frac{\text{weekly correction}}{\text{yearly correction}}$	1968 Survey	Range of 1968 survey
650	0	0	$\frac{0}{0}$	92	0	$\frac{0}{0}$	$\frac{250}{250}$	250	±60
652	250	0	$\frac{0}{0}$	157	0	$\frac{0}{0}$	$\frac{380}{380}$	380	±140
654	630	0	$\frac{0}{0}$	262	0	$\frac{0}{0}$	$\frac{670}{670}$	570	±420
656	1300	100	$\frac{0}{0}$	392	75	$\frac{0}{0}$	$\frac{900}{817}$	700	±620
658	2200	300	$\frac{0}{83}$	600	165	$\frac{0}{97}$	$\frac{1377}{1199}$	1040	±380
660	3700	760	$\frac{123}{384}$	875	300	$\frac{86}{231}$	$\frac{1783}{1377}$	1260	±410
662	5700	1500	$\frac{340}{1007}$	1025	460	$\frac{109}{319}$	$\frac{1882}{1447}$	1000	±718
664	7800	2600	$\frac{558}{1660}$	1075	600	$\frac{111}{330}$	$\frac{1976}{1531}$	900	±1908
666	10000	3900	$\frac{782}{2329}$	1300	775	$\frac{315}{509}$	$\frac{1963}{1631}$	1200	±3800
668	13000	5700	$\frac{1819}{3698}$	1750	1040	$\frac{885}{893}$	$\frac{1496}{1798}$	1640	±2400
670	17000	8060	$\frac{4323}{5900}$	2125	1350	$\frac{1496}{1241}$	$\frac{1021}{1736}$	1460	±1020
672	21500	11100	$\frac{7802}{8664}$	2450	1885	$\frac{2033}{1673}$	$\frac{845}{1570}$	1000	±2660
674	27000	15600	$\frac{12457}{12544}$	2825	2775	$\frac{2485}{2170}$	$\frac{715}{1250}$	-600	±3000
676	33000	22200	$\frac{17742}{17344}$	3500	3625	$\frac{3185}{3049}$	$\frac{543}{553}$	100	±3680
678	41000	30100	$\frac{25199}{24791}$	4450	4204	$\frac{4278}{4312}$	$\frac{144}{1}$	885	±2520
680	50800	39015	$\frac{34855}{34590}$	4750	4975	$\frac{4680}{4750}$	$\frac{135}{0}$	-1785	
682	60000	50000	$\frac{43920}{43790}$	5550	5746	$\frac{5508}{5550}$	$\frac{34}{0}$	1000	
684	73000	62000	$\frac{56886}{56790}$	7000	6050	$\frac{6990}{7000}$	$\frac{7}{0}$	2800	
686	88000	74200	$\frac{71879}{71790}$	7750	7500	$\frac{7747}{7750}$	$\frac{5}{0}$	-1800	
688	104000	92000	$\frac{87874}{87790}$	8175	8672	$\frac{8172}{8175}$	$\frac{5}{0}$	-190	
690	120700	108890	$\frac{104569}{104490}$	9000	9300	$\frac{8998}{9000}$	$\frac{5}{0}$	-1010	
692	14000	129200	$\frac{123864}{123790}$	10425	10578	$\frac{10423}{10425}$	$\frac{3}{0}$	400	
694	162400	151200	$\frac{146261}{146190}$	12250	11575	$\frac{12249}{12250}$	$\frac{2}{0}$	2300	
696	189000	175500	$\frac{172859}{172790}$	13650	13200	$\frac{13650}{13650}$	$\frac{0}{0}$	-500	
698	217000	204000	$\frac{200859}{200790}$	14375	14816	$\frac{14375}{14375}$	$\frac{0}{0}$	-1265	
700	246500	234765	$\frac{230359}{230290}$	15500	16375	$\frac{15500}{15500}$	$\frac{0}{0}$	-2235	
702	279000	269500	$\frac{262859}{262790}$	17375	17634	$\frac{17375}{17375}$	$\frac{0}{0}$	1200	
704	316000	305300	$\frac{299859}{299790}$	19525	18450	$\frac{19525}{19525}$	$\frac{0}{0}$	3100	
706	357100	343300	$\frac{340959}{340890}$	21000	20075	$\frac{21000}{21000}$	$\frac{0}{0}$	600	
708	400000	385600	$\frac{383859}{383790}$	21725	22197	$\frac{21725}{21725}$	$\frac{0}{0}$	-2490	
710	444000	432090	$\frac{427859}{427790}$	23000	23655	$\frac{23000}{23000}$	$\frac{0}{0}$	-130	
712	492000	480220	$\frac{475859}{475790}$	24650	24725	$\frac{24650}{24650}$	$\frac{0}{0}$	-180	
714	542600	531000	$\frac{526459}{526390}$	25825	25945	$\frac{25825}{25825}$	$\frac{0}{0}$	-300	
716	595300	584000	$\frac{579159}{579090}$	27400	27325	$\frac{27400}{27400}$	$\frac{0}{0}$	600	
718	652200	640300	$\frac{636059}{635990}$	29175	28992	$\frac{29175}{29175}$	$\frac{0}{0}$	130	
720	712000	699970	$\frac{695859}{659790}$	30625	30677	$\frac{30625}{30625}$	$\frac{0}{0}$		

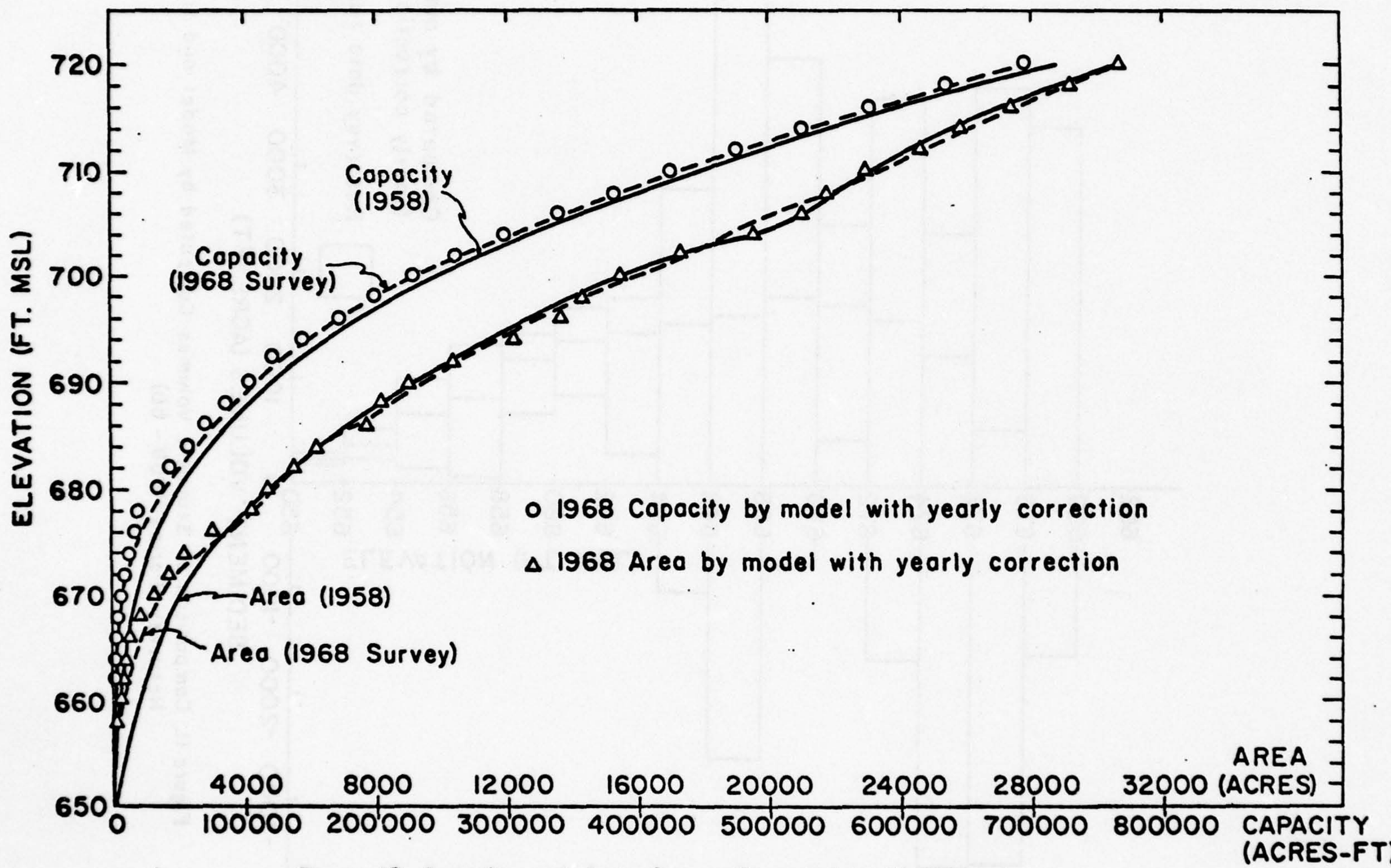

Figure 10. Capacity and Area Curves Computed by Model and from Survey (Period: 1958 - 68)

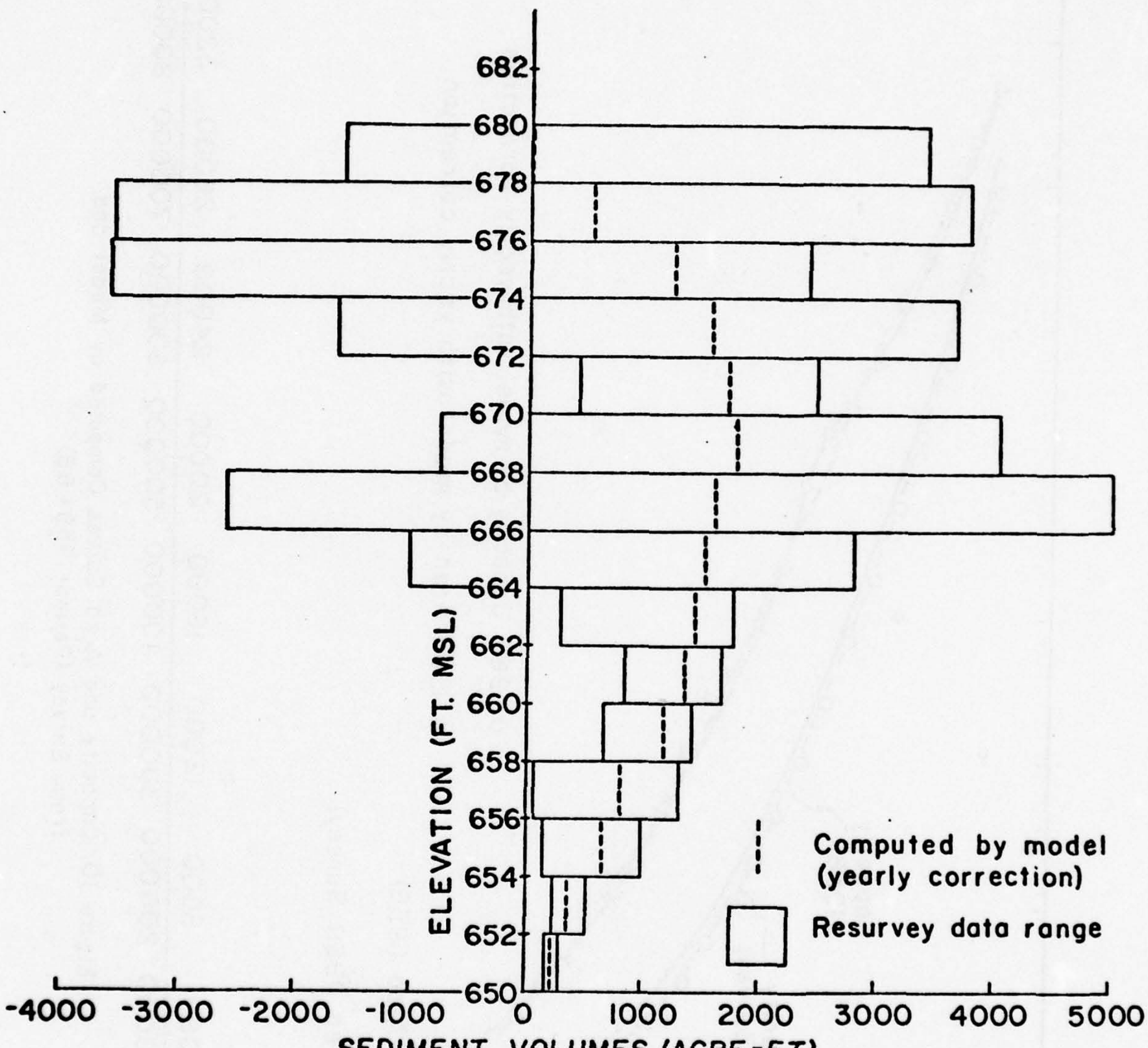

Figure 11. Comparison of Sediment Volumes Computed by Model and from Resurvey (Period: 1958 - 68)

erosion) throughout the height of the reservoir. This discrepancy is due to the fact that the model presented herein is applicable up to the average pool level prevailing during the period of reservoir operation. Development of the delta and consequent deposition or erosion in the upper reaches of reservoirs are not accounted for in the present model. Some uncertainty exists in comparing incremental sediment volumes due to inaccuracies involved in interpolating between given elevation indices of survey data. In spite of this difficulty, computed values, as shown in figure 11, lie approximately in the middle of the spread of the survey data.

Table 1 shows cumulative capacities, areas, and incremental sediment volumes computed by the model for both weekly and yearly corrections. It is found that the model results with yearly correction are closer to the survey data than those for weekly corrections. Table 2 shows model results for the 10-year corrections, which are even closer to the survey data. Thus, larger intervals of correction are found to give better results in this example. This may be explained by the fact that the area-reduction method (Borland and Miller, 1960), on which this model is based, is derived from survey data of reservoirs with sedimentation periods of 10 or more years; so this method is applicable to larger periods of sedimentation. More of this aspect of the Borland method is discussed in the next section.

C. Comparison with Borland and Miller's Original Method

The area-reduction method as suggested by Borland and Miller (1960) is used to compute revised capacities and areas after 10 years of sedimentation (1958-1968). Relevant compuations are presented in table 3. Average pool elevations and the total sediment volumes trapped in the reservoir used in this computation are the same as those used in the computer model. Comparisons of revised capacities and areas with model and survey results are shown in table 2. It is found that the model results with either the weekly, yearly or 10-year correction give better agreement with survey data than those given by Borland's original method. This establishes that definite improvement has been made by the introduction of compaction and slump corrections in the present computer model.

Table 2

Comparison of Capacities and Areas with Different Intervals of Corrections and with Borland's Method

Elev.	Original Capacity in 1958 (acre-ft)	Original Area in 1958 (acres)	Capacity after 10 years (1968) (acre-ft)				Area after 10 years (1968) (acres)			
			Survey	Model (yearly correction)	Model (10 year correction)	Original method by Borland	Survey	Model (yearly correction)	Model (10 year correction)	Original method by Borland
650	0	92	0	0	0	0	0	0	0	0
652	250	157	0	0	0	0	0	0	0	0
654	630	262	0	0	0	0	0	0	0	0
656	1300	392	100	0	0	0	75	0	0	0
658	2200	600	300	83	0	0	165	97	0	0
660	3700	875	760	384	572	0	300	231	296	0
662	5700	1025	1500	1007	1287	176	460	319	367	76
664	7800	1075	2600	1660	2039	349	600	330	385	97
666	10000	1300	3900	2329	2826	584	775	509	567	313
668	13000	1750	5700	3698	4306	1621	1040	893	909	774
670	17000	2125	8060	5900	6461	3705	1350	1241	1227	1185
672	21500	2450	11100	8664	9216	6393	1885	1673	1671	1578
674	27000	2825	15600	12594	13146	10263	2775	2170	2167	2067
676	33000	3500	22200	17344	17883	14955	3625	3049	3047	2950
678	41000	4450	30100	24791	25336	22405	4204	4312	4313	4450

Table 3

Computations for Borland Methods
(Period 1958-1968)

El.	Orig. capacity (a-ft)	Orig. area (acres)	P	A_p	1st Trial Sed. area (acres)	1st Trial Sed. vol. (a-ft)	2nd Trial Sed. area (acres)	2nd Trial Sed. vol. (a-ft)	Revised capacity (a-ft)	Revised capacity (acres)
650	0	92.5	0	0	92.5		92.5		0	0
652	250	157.5	.073	.542	157.5	250	157.5	250	0	0
654	630	262.5	.146	.778	262.5	380	262.5	380	0	0
656	1300	392.5	.219	.946	392.5	670	392.5	670	0	0
658	2200	600	.292	1.070	600	900	600	900	0	0
*660	3700	875	.365	1.162	875	1500	875	1500	0	0
**660.5		912.5	.383	1.180		1799		1824		
662	5700	1025	.438	1.227	924		949		176	76
664	7800	1075	.511	1.265	953	1877	978	1927	349	97
666	10000	1300	.584	1.277	962	1915	987	1965	584	313
668	13000	1750	.657	1.262	950	1912	976	1963	1621	774
670	17000	2125	.730	1.215	915	1865	940	1916	3705	1185
672	21500	2450	.803	1.127	849	1764	872	1812	6393	1578
674	27000	2825	.876	.980	738	1587	758	1630	10263	2067
676	33000	3500	.949	.712	536	1274	550	1308	14955	2950
678	41000	4450	1.00	0	0	536	0	550	22405	4450
					TOTAL:	18229		18595		

* First trial zero elevation
** Second trial zero elevation

Average Water Depth = 27.4 ft

$$\text{Sediment Trapped} = \frac{18760816 \times 2000}{45.78 \times 43560} = 18{,}815 \text{ acre-ft}$$

$$A_p = 2.487\, p^{0.57} (1-p)^{0.41}$$

D. Discussion of Results and Suggested Applications

The revised capacity and area curves and incremental sediment volumes calculated by the computer model for the Coralville reservoir after 10 years of sedimentation (1958-68) show good agreement with the survey data (see tables 1 and 2). The empirical area-reduction procedure as suggested by Borland and Miller (1960) has been modified for use in the present model. In addition, a procedure for compaction of deposited sediment and necessary slump corrections due to differential settling in the vicinity of zero elevation and at the sediment zone interfaces have been incorporated in the model to improve the results. Borland's original method is applicable to large sedimentation periods, say 10 years or more. This method is not quite as applicable to smaller sedimentation periods like one or two years. For example, Borland's method, when applied to the Coralville reservoir for a one-year sedimentation period, breaks down completely. The modified procedure as used in the present model permits sediment computations for any interval of sedimentation. However, accuracy decreases slightly for shorter sedimentation periods. This aspect of the present model is useful since sometimes it may be necessary to estimate the effect of sedimentation after a short period, say two or five years. For example, when optimizing the operation of a multipurpose reservoir, it may be necessary to estimate the effects of sedimentation on reservoir capacity and area relations and consequently on operation rules, and vice versa, every five years, two years or shorter periods for achieving maximum benefits.

The accuracy of the model can be improved by the following procedure. The modified procedure as used in the present model requires the placement of some preselected fraction (say β) of incoming sediment volume in the dead storage. The accuracy of the model results is sensitive to the value of β selected. An arbitrary small value of β may not improve accuracy, and is likely to be contrary to such expectation. To examine the sensitivity of β, the model was applied to the Coralville reservoir with yearly and 10-year corrections for different values of β. The results are shown in tables 4 and 5. It is observed that both the zero elevation and distribution of sediments with height are sensitive to the value of β. In this example, β=0.10 gives the best agreement with survey data.

Table 4

Comparison of Model Results with Different Values of β
(Yearly Correction)

El.	Capacity (acre-ft) after 10 years with model (yearly corrections) β=.01	β=.03	β=.10	β=.20	Survey 1968	Borland (10 years interval)
650	0	0	0	0	0	0
652	0	0	0	0	0	0
654	0	0	0	0	0	0
656	0	0	0	0	100	0
658	79	83	0	0	300	0
660	353	384	510	0	760	0
662	981	1007	1191	830	1500	176
664	1608	1660	1886	1701	2600	349
666	2277	2329	2615	2615	3900	584
668	3634	3698	3965	4016	5700	1621
670	5849	5900	6142	6244	8060	3705
672	8628	8664	8832	8958	11100	6393
674	12575	12594	12683	12815	15600	10263
676	17341	17344	17360	17490	22200	14955
678	24797	24791	24776	24902	30100	22405
Zero Elev. after 1 yr	650.15	650.44	651.28	652.24	-	-
Zero Elev. after 10 yrs.	656.75	656.58	658.71	660.49	~658.0	660.50
Total sediment Vol. (acre-ft)	16205	16210	16225	16098	10900±	18595

Table 5

Comparison of Model Results with Different Values of β (10-yearly correction)

El.	Capacity (acre-ft) after 10 years with model (10-year corrections) β =.01	β=.03	β=.10	β=.20	Survey 1968	Borland
650	0	0	0	0	0	0
652	0	0	0	0	0	0
654	0	0	0	0	0	0
656	0	0	0	0	100	0
658	0	0	0	0	300	0
660	578	572	0	0	760	0
662	1305	1287	1190	854	1500	176
664	2068	2039	2439	1751	2600	349
666	2867	2826	3748	2691	3900	584
668	4371	4306	5248	4193	5700	1621
670	6545	6461	7422	6403	8060	3705
672	9318	9216	10194	9210	11100	6393
674	13264	13146	14139	13186	15600	10263
676	18014	17883	18889	17961	22200	14955
678	25477	25336	26353	25435	30100	22405
Zero Elev.	659.47	656.68	660.62	661.96	~658.0	660.50
Total sediment Vol. (acre-ft)	15553	15664	14647	15565	10900±	18595

The value of β for best fit is likely to vary from reservoir to reservoir and from one sedimentation period to another. It is suggested that the value of β should be carefully selected by calibrating the model with known results.

It is remarkable to observe from tables 1, 2, 4, and 5, that the model results with weekly and yearly corrections (with β=.03 in tables 1 and 2, β varying in tables 4 and 5) are fairly close to the survey data. However, it is suggested that, for the best results, the interval of correction for compaction and slump should be five to ten years for larger periods (10 years or more) of sedimentation.

The present model is not applicable to the upper reaches of reservoirs. The model results should be considered valid up to the average pool level prevailing during the period of reservoir operation. Development of delta and consequent deposition or erosion in the upper reaches of reservoirs are not accounted for in the present model.

VI. SUMMARY AND CONCLUSIONS

Sedimentation in reservoirs is governed by several factors, e.g., water and sediment inflows, sediment characteristics, reservoir operation rules, shape and size of the reservoir, evaporation, etc. The interaction of all these factors presents too complex a situation to permit an analytical approach for estimating the resulting consequences relating to sedimentation. To overcome this difficulty, a simulation scheme is developed with all aspects of the problem represented.

The simulation scheme estimates the changes in reservoir profile due to sedimentation resulting from the combined effects of water and sediment inflows, reservoir operation rules, size and shape of reservoir, and evaporation. The computer simulation model developed includes several input submodels to supply necessary input data to the sedimentation submodel, which forms the heart of the simulation scheme. The input submodels include construction of synthetic time series models for water inflow, sediment inflow, and evaporation, and an operation submodel which estimates outflow and reservoir pool level using inflows, evaporation, the operation rule, and reservoir characteristics. The stochastic nature of the sedimentation process is taken care of indirectly by the introduction

of stochastic time series for inputs. Using the data generated by the input submodels, the sedimentation submodel estimates the total volume of sediment entrapped in the reservoir in a selected time interval, and then distributes this over the height of the reservoir. Deposited sediments are compacted using appropriate specific weights at the end of each time interval. Necessary corrections are applied to remove any anomalies caused by slumping due to differential compaction of different sediment components (sand, silt and clay) in the vicinity of the zero elevation and at the sediment zone interfaces. The simulation model, at the end of each time interval, outputs the water outflow, the reservoir pool elevation, the volume of deposited sediment with its distribution over the reservoir height, the resulting new zero elevation and the adjusted elevation-area-volume relationship.

The procedure for distribution of sediment over the reservoir height is based on a modified version of the empirical area-reduction method developed by Borland and Miller (1960). Borland's original method is applicable to reservoirs with relatively large periods (10 years or more) of sedimentation. A modification of Borland's procedure has been incorporated into the present model to extend its applicability to any interval of sedimentation. This modification enables the use of the model to estimate the effects of sedimentation on the reservoir profile after a short interval (one year or less), which might be important in evolving a flexible operation rule, based on a changing reservoir profile, for optimum utilization of a multipurpose reservoir.

The validity of the model was checked by application to the Coralville reservoir on the Iowa river near Iowa City, Iowa. The total period of simulation was 10 years (1958-68) and the interval of correction for compaction and slump was varied from one week to 10 years. Close agreement was observed between the model results and actual survey data. Larger intervals of correction were found to give better agreement with survey data. It has been demonstrated that the procedure for compaction and consequent slump corrections, as incorporated in the present model, gives significant improvement over Borland's original procedure.

The simulation model is quite general in operation and can be applied to any reservoir for any length of operation and for any interval of correction for compaction and slump. For application to a particular

reservoir, input submodels for generating inflows, operation submodel and sediment entrappment submodel may need some modification or replacement relevant to the reservoir in consideration.

The present model is not applicable to the upper reaches of reservoirs. The model results should be considered valid upto the average pool level prevailing during the period of reservoir operation. Development of delta and consequent deposition or erosion in the upper reaches of reservoirs are not accounted for in the present model.

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APPENDICES

APPENDIX A

Data for Input Models for the Coralville Reservoir

Table A1. Area-Capacity Relation for Coralville Reservoir

Elevation (ft)	Area (acres)	Capacity (acre-ft)
650	0	0
655	360	900
660	760	3700
665	1370	9000
670	1820	17000
675	3400	30000
680	4900	50800
685	6850	80200
690	9350	120700
695	12500	175300
700	16000	246500
705	19800	336000
710	23330	444000
715	26700	569200
720	30200	712000

Table A2. Weekly Mean (μ_i) of Iowa River Flows into Reservoir (Week No. 1 ≡ 1 October-7)

i	μ_i (acre-ft)	i	μ_i (acre-ft)	i	μ_i (acre-ft)	i	μ_i (acre-ft)
1	15847.35	14	11344.42	27	35923.82	40	40426.76
2	14167.78	15	12660.44	28	37603.41	41	39110.75
3	12659.10	16	14169.33	29	39112.07	42	37601.85
4	11343.32	17	15849.03	30	40427.87	43	35922.26
5	10239.57	18	17675.10	31	41531.60	44	34096.19
6	9363.95	19	19620.80	32	42407.25	45	32150.37
7	8729.36	20	21657.94	33	43041.94	46	30113.26
8	8344.83	21	23756.71	34	43426.37	47	28014.48
9	8216.06	22	25886.60	35	43555.14	48	25884.58
10	8345.05	23	28016.37	36	43426.14	49	23754.82
11	8729.80	24	30115.14	37	43041.39	50	21656.03
12	9364.73	25	32152.16	38	42406.46	51	19619.03
13	10240.46	26	34097.87	39	41530.73	52	17673.32

Table A3. Weekly Standard Deviation (σ_i) of Iowa River Flows into Reservoir (Week No. 1 ≡ 1 October-7)

i	σ_i (acre-ft)	i	σ_i (acre-ft)	i	σ_i (acre-ft)	i	σ_i (acre-ft)
1	12246.5	14	41051.0	27	31392.3	40	36160.9
2	8820.0	15	40682.8	28	37270.3	41	34077.6
3	6372.0	16	38691.7	29	43002.7	42	32784.2
4	5254.6	17	35379.3	30	48046.9	43	32170.0
5	5689.6	18	31204.7	31	51952.6	44	32003.9
6	7733.1	19	26730.9	32	54411.6	45	31975.2
7	11259.5	20	22557.6	33	55287.8	46	31745.9
8	15968.7	21	19250.8	34	54625.4	47	31006.0
9	21416.0	22	17274.9	35	52633.9	48	29526.1
10	27061.1	23	16938.8	36	49657.8	49	27198.2
11	32330.4	24	18360.3	37	46100.8	50	24059.4
12	36885.3	25	21453.5	38	42416.9	51	20295.3
13	39687.0	26	25941.7	39	39000.7	52	16221.4

Table A4. Weekly Lag One Serial Correlation (ρ_i) of Iowa River Flows into Reservoir (Week No. 1 ≡ 1 October-7)

i	ρ_i	i	ρ_i	i	ρ_i	i	ρ_i
1	0.6283	14	0.7322	27	0.6283	40	0.7322
2	0.6283	15	0.5729	28	0.6282	41	0.5729
3	0.7969	16	0.6103	29	0.7969	42	0.6103
4	0.9201	17	0.6960	30	0.9201	43	0.6960
5	0.8047	18	0.6558	31	0.8047	44	0.6558
6	0.6064	19	0.6076	32	0.6064	45	0.6076
7	0.5797	20	0.7305	33	0.5797	46	0.7305
8	0.6777	21	0.9022	34	0.6777	47	0.9022
9	0.6817	22	0.8670	35	0.6817	48	0.8670
10	0.6093	23	0.6622	36	0.6093	49	0.6622
11	0.6710	24	0.5649	37	0.6710	50	0.5649
12	0.8581	25	0.6464	38	0.8581	51	0.6464
13	0.9079	26	0.6970	39	0.9079	52	0.6970

Table A5. Empirical Cumulative Frequency Distribution, $F(\xi_i)$ of the Independent Stochastic Component of Iowa River Flows into Reservoir

$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}
0.00	-5.560	0.26	-0.331	0.52	-0.139	0.78	0.095
0.02	-1.578	0.28	-0.314	0.54	-0.120	0.80	0.141
0.04	-0.951	0.30	-0.300	0.56	-0.104	0.82	0.212
0.06	-.0800	0.32	-0.286	0.58	-0.090	0.84	0.297
0.08	-0.674	0.34	-0.272	0.60	-0.075	0.86	0.352
0.10	-0.614	0.36	-0.258	0.62	-0.064	0.88	0.456
0.12	-0.565	0.38	-.0246	0.64	-0.055	0.90	0.616
0.14	-0.511	0.40	-0.235	0.66	-0.044	0.92	0.851
0.16	-0.477	0.42	-0.224	0.68	-0.034	0.94	1.280
0.18	-0.440	0.44	-0.211	0.70	-0.023	0.96	1.876
0.20	-0.407	0.46	-0.191	0.72	-0.005	0.98	2.993
0.22	-0.379	0.48	-0.172	0.74	0.015	1.00	10.362
0.24	-0.350	0.50	-0.153	0.76	0.054		

Table A6. Weekly Mean (μ_{s_i}) of Iowa River Sediment Inflows into Reservoir (Week No. 1 ≡ 1 October-7)

i	μ_{s_i} (tons)	i	μ_{s_i} (tons)	i	μ_{s_i} (tons)	i	μ_{s_i} (tons)
1	10635.2	14	462.5	27	57339.1	40	80908.8
2	19500.6	15	29224.5	28	60755.3	41	72941.8
3	7562.6	16	864.1	29	60562.5	42	81639.6
4	20534.9	17	31611.6	30	133640.5	43	44858.3
5	14789.9	18	48579.1	31	30093.3	44	26809.6
6	11169.2	19	26612.1	32	17604.5	45	52613.1
7	6935.1	20	44944.3	33	30699.4	46	41186.7
8	5743.5	21	11939.9	34	40856.1	47	23406.0
9	13597.5	22	2110.5	35	42539.3	48	13447.1
10	5232.3	23	50095.0	36	62643.7	49	12469.9
11	8867.9	24	49893.5	37	70532.1	50	6909.4
12	6066.2	25	60178.6	38	53329.8	51	6333.8
13	2998.5	26	40955.9	39	73782.8	52	8914.5

Table A7. Weekly Standard Deviation (σ_{s_i}) of Iowa River Sediment Inflow into Reservoir (Week No. 1 ≡ 1 October-7)

i	σ_{s_i} (tons)	i	σ_{s_i} (tons)	i	σ_{s_i} (tons)	i	σ_{s_i} (tons)
1	11574.6	14	267.6	27	78937.3	40	72836.2
2	21588.1	15	13347.0	28	70545.9	41	103228.0
3	7538.9	16	667.7	29	56497.4	42	123676.0
4	33815.4	17	28570.7	30	138382.8	43	45608.5
5	18856.0	18	43423.2	31	17124.4	44	27234.3
6	12339.4	19	23928.6	32	11091.6	45	30677.9
7	8443.6	20	40944.5	33	20139.4	46	41376.8
8	6602.2	21	10824.1	34	40950.7	47	14190.6
9	14879.1	22	1879.3	35	44075.0	48	10383.8
10	5948.3	23	32870.4	36	49497.8	49	10472.8
11	14535.3	24	33172.5	37	65293.1	50	5889.5
12	7166.5	25	36830.0	38	62691.5	51	8497.7
13	2862.9	26	44088.5	39	41767.5	52	13249.0

Table A8. Empirical Cumulative Frequency Distribution, $F(\xi_{s_i})$ of the Independent Stochastic Component, ξ_{s_i}, of Iowa River Sediment Inflows into Reservoir

$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}	$F(\xi_{s_i})$	ξ_{s_i}
0.00	-2.200	0.26	-0.497	0.52	-0.307	0.78	0.281
0.02	-1.374	0.28	-0.488	0.54	-0.281	0.80	0.401
0.04	-0.970	0.30	-0.475	0.56	-0.257	0.82	0.569
0.06	-0.873	0.32	-0.463	0.58	-0.244	0.84	0.722
0.08	-0.792	0.34	-0.447	0.60	-0.226	0.86	0.863
0.10	-0.748	0.36	-0.432	0.62	-0.209	0.88	1.086
0.12	-0.680	0.38	-0.423	0.64	-0.189	0.90	1.472
0.14	-0.635	0.40	-0.402	0.66	-0.138	0.92	1.902
0.16	-0.601	0.42	-0.387	0.68	-0.107	0.94	2.245
0.18	-0.577	0.44	-0.380	0.70	-0.052	0.96	2.542
0.20	-0.563	0.46	-0.360	0.72	0.015	0.98	2.994
0.22	-0.544	0.48	-0.344	0.74	0.089	1.00	3.514
0.24	-0.531	0.50	-0.326	0.76	0.171		

Table A9. Weekly Mean (μ_{E_i}) Pan Evaporation (Week No. 1 ≡ 1 October-7)

i	μ_{E_i} (in)	i	μ_{E_i} (in)	i	μ_{E_i} (in)	i	μ_{E_i} (in)
1	0.859	14	0.059	27	0.854	40	1.700
2	0.889	15	0.059	28	0.981	41	1.637
3	0.718	16	0.067	29	1.059	42	1.628
4	0.783	17	0.079	30	1.151	43	1.662
5	0.688	18	0.079	31	1.351	44	1.569
6	0.570	19	0.079	32	1.262	45	1.473
7	0.472	20	0.138	33	1.355	46	1.508
8	0.399	21	0.169	34	1.478	47	1.363
9	0.315	22	0.236	35	1.502	48	1.386
10	0.236	23	0.315	36	1.450	49	1.244
11	0.157	24	0.433	37	0.657	50	1.187
12	0.079	25	0.531	38	1.630	51	1.082
13	0.067	26	0.609	39	1.786	52	1.124

Table A10. Empirical Cumulative Frequency Distribution, $F(\xi_{E_i})$, of the Stochastic Component, ξ_{E_i} of Pan Evaporation

$F(\xi_{E_i})$	ξ_{E_i}	$F(\xi_{E_i})$	ξ_{E_i}	$F(\xi_{E_i})$	ξ_{E_i}	$F(\xi_{E_i})$	ξ_{E_i}
0.00	-2.383	0.26	-0.240	0.52	-0.003	0.78	0.230
0.02	-1.599	0.28	-0.199	0.54	0.005	0.80	0.279
0.04	-1.307	0.30	-0.156	0.56	0.011	0.82	0.345
0.06	-1.125	0.32	-0.122	0.58	0.014	0.84	0.424
0.08	-0.979	0.34	-0.094	0.60	0.025	0.86	0.541
0.10	-0.832	0.36	-0.078	0.62	0.032	0.88	0.685
0.12	-0.696	0.38	-0.056	0.64	0.039	0.90	0.851
0.14	-0.603	0.40	-0.040	0.66	0.048	0.92	0.992
0.16	-0.524	0.42	-0.031	0.68	0.065	0.94	1.181
0.18	-0.457	0.44	-0.027	0.70	0.085	0.96	1.497
0.20	-0.412	0.46	-0.027	0.72	0.102	0.98	1.741
0.22	-0.328	0.48	-0.014	0.74	0.138	1.00	7.262
0.24	-0.285	0.50	-0.010	0.76	0.177		

Table A11. Weekly Pan Evaporation Coefficient (C_{p_i})

i	C_{p_i}	i	C_{p_i}	i	C_{p_i}	i	C_{p_i}
1	0.980	14	0.500	27	0.460	40	0.840
2	0.980	15	0.450	28	0.480	41	0.860
3	0.980	16	0.400	29	0.480	42	0.900
4	0.970	17	0.410	30	0.490	43	0.920
5	0.920	18	0.420	31	0.500	44	0.920
6	0.860	19	0.420	32	0.540	45	0.930
7	0.800	20	0.430	33	0.580	46	0.940
8	0.760	21	0.430	34	0.610	47	0.970
9	0.680	22	0.440	35	0.620	48	0.970
10	0.600	23	0.450	36	0.680	49	0.970
11	0.540	24	0.450	37	0.770	50	0.970
12	0.520	25	0.460	38	0.800	51	0.975
13	0.500	26	0.460	39	0.820	52	0.980

APPENDIX B

List of Computer Program, Example Data and Output

```
C      *******************************************
C
C                     PROGRAM  SEDRES
C
C      *******************************************
C
C
C      THIS IS A COMPREHENSIVE RESERVOIR SIMULATION MODEL TO COMPUTE SEDIMENT
C      VOLUMES DEPOSITED OVER THE HEIGHT OF RESERVOIRS. USING APPROPRIATE
C      INPUT MODELS ON WATER INFLOW,SEDIMENT INFLOW,EVAPORATION AND RESERVOIR
C      OPERATION, THE PROGRAM SEDRES COMPUTES SEDIMENT VOLUMES TRAPPED IN THE
C      RESERVOIR,DISTRIBUTES THEM OVER THE HEIGHT,COMPACTS THEM AT SPECIFIED
C      INTERVALS,AND APPLY NECESSARY CORRECTIONS FOR SEDIMENT SLUMP. THE
C      PROGRAM OUTPUTS NEW ZERO ELEVATION,SEDIMENT VOLUMES DEPOSITED OVER THE
C      HEIGHT,AND ADJUSTED AREA-CAPACITY RELATION OF THE RESERVOIR.
C
C
       DOUBLE PRECISION RANU,TX
       INTEGER PARAM
       REAL INFISC
       REAL IUSD(144),IMCD(144)
       DIMENSION SPWT(2,520,3),ELEV(36),AREA(36),VOLUME(36),AAREA(36),AVO
      1L(36),V(520,36),X(520,3),AMPC(52),ASSL(2,2,3),XI(3),FP(520),HP(36)
       DIMENSION QI(520),QS(520),QE(520),PROB(51)
       DIMENSION ASNL(2,2,3),P(3,3)
       DIMENSION RHOIN(3,52)
       DIMENSION INFISC(51),CORRIN(3,52), TSTDVI(52), TMEANI(52)
       DIMENSION TSTDVE(52),TMEANE(52),EVISCD(51)
       DIMENSION SEDISC(51),TSTDVS(52),TMEANS(52)
       DIMENSION DHEAD(144),ELPREO(52)
       COMMON ASSL,TT,SPWT,CPIFR,TE,BETA,EMM,ENN,ACQI,ACQS,NUOC,HH,V,IDS,
      1INS,AVOL,AAREA,X,GGAMA,XSAVE,DELTA
       COMMON/SUBINF/XYX1,XYX2,XYX3,TMEIN,TSDIN,CORRIN,TSTDVI ,TMEANI ,IN
      1FISC , NRDERI,RHOIN
       COMMON/SUBEVA/TSTDVE,TMEANE,EVISCD
       COMMON/SUBSEG/TSTDVS,TMEANS,SEDISC
       COMMON/GENER/ELEV,AREA,VOLUME,NTI,HEAD,NTIYR,NUMBER,III,DAMHT
      1,ZELEV,AMPC,AVSTO
       COMMON/GENERA/RANU,EPSILO,EATA,PROB,QI,QS,QE,QER,NN
       COMMON/SUBO/IUSD,IMCD,ELPREO,DHEAD,OUTFL
       COMMON/OPER/K,IM,RESUR,RESVOL
       COMMON/SUBOPE/XI,X1,X2,X3
       COMMON/ABC/PARAM
C*****
C*****   AREA - ACRES
C*****   VOLUME - ACRE-FT
C*****   ELEV - FT
C*****   QI - ACRE-FT
C*****   QS - TONS   (PER TIME INCREMENT)
C*****   SPWT - LBS/CU FT
C****    DELTA- LOWER LIMIT OF SEDIMENT VOLUME USED AS A CRITERION FOR
C        TERMINATING SEDIMENT REDISTRIBUTION DUE TO SLUMP CORRECTIONS.
C        ITS VALUE IS SELECTED CONSIDERING UNITS USED AND ACCURACY DESIRED
C*****
C*****
C*****   THE FOLLOWING INPUTS AND CALCULATIONS ARE FOR USE IN THE SEDIMENT
C*****   SUBROUTINE
C*****
```

```
C*****
C
C     READ INDEX VARIABLE PARAM
C
C     PARAM=1 FOR HISTORICAL WATER INFLOW DATA
C     PARAM=2 FOR GENERATED WATER INFLOW DATA
C
      READ(5,3) PARAM
C
C*****   INPUT SEDIMENT CHARACHTERISTICS DATA AND CALCULATION OF COEFFICIENTS
C*****   USED IN DENSITY CALCULATIONS
C*****
C*****
C*****   READ NUMBER OF YEARS OF RESERVOIR OPERATION,NN
C*****
      READ(5,3) NN
      NN=NN*52
      READ(5,75) DELTA
C
      IF(PARAM.EQ.2) GO TO 552
      READ(5,33)(QI(I),I=1,2)
      READ(5,35)(QI(I),I=3,520)
552   DO 555 KK=1,2
  555 READ(5,1) ((ASNL(KK,I,J),J=1,3),I=1,2)
C*****
C*****   ASNL - SEDIMENT CHARACHTERISTICS FOR CALCULATION OF DENSITIES
C*****   KK - LEVEL (1 - LOWER, 2 - UPPER)
C*****   I - (1 - NATURAL DENSITY, 2 - COMPACTION COEFFICIENT)
C*****   J - SEDIMENT COMPONENT (1 - CLAY, 2 - SILT, 3 - SAND)
C*****
      READ(5,1) ((P(I,J),J=1,3),I=1,3)
C*****
C*****   P(I,J) - FRACTION OF SEDIMENT COMPONENT I IN SEDIMENT COMPONENT ZONE J
C*****
C*****   P(I,J) IS ADJUSTED TO BE RELATIVE AMOUNTS IN ZONE J OF COMPONENTS I
C*****
      DO558J=1,3
      B=0.
      DO557I=1,3
  557 B=B+P(I,J)
      DO558I=1,3
  558 P(I,J)=P(I,J)/B
      DO556KK=1,2
      DO556I=1,2
      DO556J=1,3
      ASSL(KK,I,J)=0.
      DO556KT=1,3
  556 ASSL(KK,I,J)=ASSL(KK,I,J)+ASNL(KK,I,KT)*P(KT,J)
C*****
C*****   X1,X2,X3 - FRACTIONS OF INCOMING SEDIMENT THAT ARE COMPONENTS 1,2,3
C*****
      READ(5,1) X1,X2,X3
      XI(1)=X1
      XI(2)=X2
      XI(3)=X3
C*****
C*****   IRESTY  - THE NUMERICAL DESIGNATION OF THE TYPE OF THE RESERVOIR, 1 - 4
      READ(5,3) IRESTY
```

```
C*****
C*****
C*****   INPUT OF ELEVATION-AREA VOLUME RELATION FOR THE RESERVOIR AND ASSIGN
C*****   TO PERMANENT ARRAY
C*****
      READ(5,3) NUMBER
      READ(5,8 ) (ELEV(I),AREA(I),VOLUME(I),I=1,NUMBER)
      DO 770 I=1,NUMBER
      AAREA(I)=AREA(I)
  770 AVOL(I)=VOLUME(I)
C*****
C*****   CHOOSE TYPE CURVE CONSTANTS FOR DETERMINING RESERVOIR ZERO ELEVATION
C*****
      EMM=1.85
      ENN=0.36
      IF( IRESTY.EQ.2) GOTO771
      IF( IRESTY.EQ.3) GOTO772
      IF( IRESTY.EQ.4) GOTO773
      GOTO774
  771 EMM=0.57
      ENN=0.41
      GOTO774
  772 EMM=1.15
      ENN=2.32
      GOTO774
  773 EMM=-0.25
      ENN=1.34
C*****
C*****   INITIALIZE COEFFICIENTS AND PARAMETERS USED IN SEDIMENT CALCULATIONS
C*****
  774 III=NUMBER-1
      BETA=0.03
      NTIYR=52
      READ(5,3) NTI
C*****
C*****   READ DATA FOR RESERVOIR EVAPORATION CALCULATION
C*****
      READ(5,6)  (AMPC(I),I=1,52)
      GGAMA=ASSL(1,1,1)*X1+ASSL(1,1,2)*X2+ASSL(1,1,3)*X3
C*****
C*****   READ ARRAYS OF PARAMETERS USED IN INFLOW DATA GENERATION
C*****
      READ(5,3) NRDERI
      READ(5,6)  (PROB(I),I=1,51)
      READ(5,6)  (INFISC(I), I=1,51)
      DO860 K=1,NRDERI
  860 READ(5,6)  (RHOIN(K,I),I=1,52)
      CALL CALCMA  (NRDERI ,RHOIN,CORRIN)
      READ(5,6)  (TMEANI (I),I=1,52)
      READ(5,6)  (TSTDVI (I),I=1,52)
      READ(5,6)  TMEIN,TSDIN
C*****
C*****   READ ARRAYS OF PARAMETERS USED IN SEDIMENT DATA GENERATION
C*****
      RANU=.2
      READ(5,6) XYX1,XYX2,XYX3
      READ(5,6)  (SEDISC(I),I=1,51)
      READ(5,6)  (TMEANS (I),I=1,52)
```

```
      READ(5,6) (TSTDVS (I),I=1,52)
      READ(5,6) (TMEANE(I),I=1,52)
      READ(5,6) (EVISCD(I),I=1,51)
      DO 1000 I=1,52
      TSTDVE(I)=.3805
 1000 CONTINUE
C
C     READ ARRAYS OF RESERVOIR STORAGE,OUTFLOW AND OPERATION CHARACTERISTICS
C
      READ(5,6) (DHEAD(I),I=1,144)
      READ(5, 6)(IUSD(I),I=1,144)
      READ(5, 6)(IMCD(I),I=1,144)
      READ(5,8) DAMHT
      READ(5,3) IDS
      DO 150 I=1,NTIYR
  150 READ(5,8) ELPREO(I)
C
C     DATA OUTPUT AND INITIALIZATION
C
      WRITE(6,10)
      IF(PARAM.EQ.1) GO TO 155
      IF(PARAM.EQ.2) GO TO 157
155   WRITE(6,71)
      GO TO 160
157   WRITE(6,72)
160   WRITE(6,77)
      WRITE(6,78) (((ASNL(KK,I,J),J=1,3),I=1,2),KK=1,2)
      WRITE(6,79) (((ASSL(KK,I,J),J=1,3),I=1,2),KK=1,2)
      WRITE(6,10)
      WRITE(6,80) GGAMA
      WRITE(6,76) DELTA
      WRITE(6,73) BETA
      WRITE(6,10)
      WRITE(6,81)
      WRITE(6,82) (XI(I),I=1,3)
      WRITE(6,10)
      WRITE(6,84)
      WRITE(6,9) (TMEANI(I),I=1,52)
      WRITE(6,85)
      WRITE(6,9) (TSTDVI(I),I=1,52)
      WRITE(6,10)
      WRITE(6,86) IDS
      WRITE(6,87) NTI
      WRITE(6,10)
      WRITE(6,88)
      WRITE(6,70) (ELEV(I),AREA(I),VOLUME(I),I=1,NUMBER)
      WRITE(6,89)
      WRITE(6,70) (ELPREO(I),I=1,52)
      WRITE(6,10)
      HH=0.
      NUOC=0
      ACQI=0.
      ACQS=0.
      TT=AREA(1)
      RESVOL=0.
      ZELEV=ELEV(1)
      XSAVE=0.
      CALL INPUTS
```

```
      MM=NN/52
      IN=1
      WRITE(6,10)
      DO 200 IIM=1,MM
      IIMM=IIM*52
      WRITE(6,13) IIM
      WRITE(6,15) (QI(MK),MK=IN,IIMM)
      WRITE(6,14) IIM
      WRITE(6,15) (QS(MK),MK=IN,IIMM)
      WRITE(6,16) IIM
      WRITE(6,19) (QE(MK),MK=IN,IIMM)
      IN=IIMM+1
  200 CONTINUE
      CALL OPERAT
      WRITE(6,90)
C
    1 FORMAT(9F5.0)
    2 FORMAT(18F4.0)
    3 FORMAT(I5)
    4 FORMAT(2(5X,F10.3))
    5 FORMAT(F10.3,3I5)
    6 FORMAT(8F10.0)
    7 FORMAT(10F10.3)
    8 FORMAT(3F10.2)
    9 FORMAT( 8(1X,F10.3))
   10 FORMAT(///)
   13 FORMAT(//5X,'RESERVOIR INFLOW TIME SERIES NUMBER ',I2,/,10X,'(ACRE
     *-FT.)',/)
   14 FORMAT(//5X,'SEDIMENT INFLOW TIME SERIES NUMBER ',I2,/,10X,'(TONS)
     *',/)
   15 FORMAT(10(1X,F8.0))
   16 FORMAT(//5X,'PAN EVAPORATION TIME SERIES NUMBER ',I2,/,10X,'(IN.)'
     *,/)
   19 FORMAT(12(1X,F6.3))
   20 FORMAT(16I5)
   25 FORMAT(16F5.3)
   30 FORMAT(10I8)
   33 FORMAT(56X,F8.1,F8.1)
   35 FORMAT(9(F8.1),8X)
   50 FORMAT(8I10)
   55 FORMAT(8(1X,I10))
   60 FORMAT(20I4)
   70 FORMAT(3(1X,F13.2))
71    FORMAT(10X,10('*'),'HISTORICAL WATER INFLOW DATA USED',10('*'),//)
72    FORMAT(10X,10('*'),'GENERATED  WATER INFLOW DATA USED',10('*'),//)
73    FORMAT(5X,'BETA=',F6.3,/)
 75   FORMAT(F14.7)
 76   FORMAT(5X,'DELTA=',F10.7,3X,'ACRE-FT.',/)
77    FORMAT(5X,'SEDIMENT CHARACTERISTICS :',/)
78    FORMAT(5X,'ASNL :',//, 6(1X,F10.3))
79    FORMAT(5X,'ASSL :',//, 6(1X,F10.3))
80    FORMAT(5X,'GGAMA=',F10.3,3X,'LBS./CFT',/)
81    FORMAT(5X,'SEDIMENT INFLOW FRACTIONS :',/)
82    FORMAT(5X,'CLAY=',F6.3,5X,'SILT=',F6.3,5X,'SAND=',F6.3,/)
84    FORMAT(5X,'WEEKLY MEANS OF WATER INFLOW(A-FT) :',/)
85    FORMAT(/,5X,'WEEKLY STANDARD DEVIATIONS OF WATER INFLOW(A-FT) :',/
     *)
86    FORMAT(5X,'IDS=',I5,/)
```

```
87     FORMAT(5X,'NTI=',I5,/)
88     FORMAT(5X,'INITIAL RESERVOIR CHARACTERISTICS :',/ /,9X,'ELEV.'
      *,8X,'AREA',8X,'VOLUME',/)
89     FORMAT(//,5X,'RESERVOIR OPERATION PLAN(WEEKLY ELEVATIONS) :',/)
   90 FORMAT(1H1)
C*****
C*****
       STOP
       END


C  ----------------------------------------------------------
C
      SUBROUTINE CALCMA (K,ZR1,R)
C
C  ----------------------------------------------------------
C
C     THIS SUBROUTINE CALCULATES WEEKLY VARIANCES OF INDEP. STOCH. COMPONENTS
C     OF WATER INFLOW SERIES
C
      DIMENSION ZR(3,52),ZR1(3,52),R(3,52),DUM(52),ZD(156)
      EQUIVALENCE(ZD(1),ZR(1,1))
      DO 10 I=1,K
      DO 10 J=1,52
   10 ZR(I,J)=ZR1(I,J)
      IF(K.EQ.2)GOTO200
      IF(K.EQ.3)GOTO300
      DO100I=1,52
  100 R(1,I)=ZR(1,I)
      DO 101 I=1,52
  101 ZD(I)=SQRT(1.-R(1,I)*R(1,I))
      RETURN
  200 DO421I=1,52
      IK1=I-1
      IK2=I-2
      IF(IK1.LT.1)IK1=IK1+52
      IF(IK2.LT.1)IK2=IK2+52
      D=1.-ZR(1,IK2)*ZR(1,IK2)
      R(1,IK1)=(ZR(1,IK1)-ZR(1,IK2)*ZR(2,IK2))/D
      R(2,IK2)=(ZR(2,IK2)-ZR(1,IK1)*ZR(1,IK2))/D
  421 CONTINUE
      DO201I=1,52
      IK1=I-1
      IK2=I-2
      IF(IK1.LT.1)IK1=IK1+52
      IF(IK2.LT.1)IK2=IK2+52
      DUM(I)=SQRT(1.-R(1,IK1)*R(1,IK1)-R(2,IK2)*R(2,IK2)-2.*R(1,IK1)*R(2
     1,IK2)*ZR(1,IK2))
  201 CONTINUE
```

```
      DO202I=1,52
202   ZD(I)=DUM(I)
      RETURN
300   DO431I=1,52
      IK1=I-1
      IK2=I-2
      IK3=I-3
      IF(IK1.LT.1) IK1=IK1+52
      IF(IK2.LT.1) IK2=IK2+52
      IF(IK3.LT.1) IK3=IK3+52
      D=1.+2.*ZR(1,IK2)*ZR(2,IK3)*ZR(1,IK3)-ZR(1,IK3)*ZR(1,IK3)-ZR(1,IK2
     1)*ZR(1,IK2)-ZR(2,IK3)*ZR(2,IK3)
      R(1,IK1)=(ZR(1,IK1)*(1.-ZR(1,IK3)*ZR(1,IK3))+ZR(1,IK3)*ZR(1,IK2)*Z
     1R(3,IK3)-ZR(1,IK2)*ZR(2,IK2)-ZR(2,IK3)*ZR(3,IK3)+ZR(1,IK3)*ZR(2,IK
     22)*ZR(2,IK3))/D
      R(2,IK2)=(ZR(2,IK2)*(1.-ZR(2,IK3)*ZR(2,IK3))+ZR(1,IK2)*ZR(2,IK3)*Z
     1R(3,IK3)-ZR(1,IK2)*ZR(1,IK1)-ZR(1,IK3)*ZR(3,IK3)+ZR(1,IK3)*ZR(2,IK
     23)*ZR(1,IK1))/D
      R(3,IK3)=(ZR(3,IK3)*(1.-ZR(1,IK2)*ZR(1,IK2))+ZR(1,IK3)*ZR(1,IK2)*Z
     1R(1,IK1)-ZR(1,IK3)*ZR(2,IK2)-ZR(2,IK3)*ZR(1,IK1)+ZR(1,IK2)*ZR(2,IK

     22)*ZR(2,IK3))/D
431   CONTINUE
      DO301I=1,52
      IK1=I-1
      IK2=I-2
      IK3=I-3
      IF(IK1.LT.1) IK1=IK1+52
      IF(IK2.LT.1) IK2=IK2+52
      IF(IK3.LT.1) IK3=IK3+52
      DUM(I)=SQRT(1.-R(1,IK1)*R(1,IK1)-R(2,IK2)*R(2,IK2)-R(3,IK3)*R(3,IK
     13)-2.*R(1,IK1)*R(2,IK2)*ZR(1,IK2)-2.*R(1,IK1)*R(3,IK3)*ZR(2,IK3)-2
     2.*R(2,IK2)*R(3,IK3)*ZR(1,IK3))
301   CONTINUE
      DO302I=1,52
302   ZD(I)=DUM(I)
      RETURN
      END
```

```
C
C  ----------------------------------------------------------
C
      SUBROUTINE INPUTS
C
C  ----------------------------------------------------------
C
      DOUBLE PRECISION RANU,TX
      INTEGER PARAM
      REAL INFISC
      DIMENSION INFISC (51),CORRIN(3,52),TSTDVI (52),TMEANI(52)
      DIMENSION QI(520),QS(520),QE(520),PROB(51)
      DIMENSION SEDISC(51),EVISCD(51),TSTDVS(52),TMEANS(52)
      DIMENSION RHOON(520),RHOIN(3,52)
      DIMENSION TSTDVE(52),TMEANE(52)
      COMMON/SUBINF/XYX1,XYX2,XYX3,TMEIN,TSDIN,CORRIN,TSTDVI ,TMEANI ,IN
     1FISC ,NRDERI ,RHOIN
      COMMON/SUBEVA/TSTDVE,TMEANE,EVISCD
      COMMON/SUBSEG/TSTDVS,TMEANS,SEDISC
      COMMON/GENERA/RANU,EPSILO,EATA,PROB,QI,QS,QE,QER,NN
      COMMON/GENER/ELEV,AREA,VOLUME,NTI,HEAD,NTIYR,NUMBER,III,DAMHT
     1,ZELEV,AMPC,AVSTO
      COMMON/OPER/K,IM,RESUR,RESVOL
      COMMON/ABC/PARAM
C*****
C*****   THIS SUBROUTINE GENERATES THE TIME SERIES FOR THE RESERVOIR
C*****   INFLOW,SEDIMENT INFLOW,AND PAN EVAPORATION
C*****
C*****
C*****   I - MONTH OF THE YEAR, STARTING FROM 1ST OCTOBER.
C*****   RANU - RANDOM NUMBER FROM THE UNIFORM DISTRIBUTION
C*****   II - SUBSCRIPT OF IND. STOCH. COMPONENT CUMULATIVE DISTRIBUTION ARRAY
C*****   EPSILO - RANDUM NUMBER WHICH IS THE INDEPENDENT STOCHASTIC COMPONENT
C*****   OF RESERVOIR INFLOW SERIES
C*****   E - RANDUM NUMBER WHICH IS INDEPENDENT STOCHASTIC COMPONENT OF
C*****   SEDIMENT INFLOW TIME SERIES
C*****   J1 - PREVIOUS WEEK OF THE YEAR
C*****   J2 - SECOND PREVIOUS WEEK OF THE YEAR
C*****   J3 - THIRD PREVIOUS WEEK OF THE YEAR
C*****   INFISC  - ARRAY OF IND. STOCH. COMPONENT FOR CUMULATIVE DISTRIBUTION
C*****   OF THE RESERVOIR INFLOW TIME SERIES
C*****   SEDISC - ARRAY OF IND. STOCH. COMPOMENT FOR CUMULATIVE DISTRIBUTION
C*****   OF SEDIMENT INFLOW TIME SERIES
C*****   EVISCD - ARRAY OF IND. STOCH. COMPONENT FOR CUMULATIVE DISTRIBUTION
C*****   OF PAN EVAPORATION TIME SERIES
C*****   PROB - INDEPENDENT STOCHASTIC COMPONENT CUMULATIVE DISTRIBUTI65 16
C*****   CORRIN - ARRAYS OF WEEKLY COEFFICIENTS FOR MARKOV DEPENDENCE MODEL
C*****   FOR RESERVOIR INFLOW TIME SERIES MODEL
C*****   TMEANS - ARRAY OF WEEKLY MEANS FOR SEDIMENT INFLOW
C*****   TSTDVS - ARRAY OF WEEKLY STANDARD DEVIATION FOR SEDIMENT INFLOW
C*****   NRDERI  - ORDER OF MARKOV MODEL USED FOR RESERVOIR INFLOW (1-3)
C
      LL=0
      IF(PARAM.EQ.1) GO TO 1000
C*****   TMEANI  - ARRAY OF WEEKLY MEANS FOR RESERVOIR INFLOW
C*****   TSTDVI  - ARRAY OF WEEKLY STANDARD DEVIATIONS FOR RESERVOIR INFLOW
C*****   TMEANE - ARRAY OF WEEKLY MEANS FOR PAN EVAPORATION
C*****   TSTDVE - ARRAY OF WEEKLY STANDARD DEVIATIONS FOR PAN EVAPORATION
```

```
C*****
C*****
      DO 102 K1=1,NRDERI
      DO 101 L=1,NN
      IL=L-IFIX((L-.5)/52.)*52
      LLL=L+LL
  101 RHOON(LLL)=RHOIN(K1,IL)
      LL=LL+52
  102 CONTINUE
C
C     WATER INFLOW SERIES GENERATION
C
      DO 200 K=1,NN
      I=K-IFIX((FLOAT(K)-.5)/52.)*52
      J1=I-1
      IF(NRDERI .EQ.1) GOTO13
      J2=I-2
      IF(NRDERI .EQ.2) GOTO14
      J3=I-3
      IF(J3.GT.0) GOTO10
      IF(J3.EQ.-2) GOTO11
      IF(J3.EQ.-1) GOTO12
      J3=52
      GOTO10
   12 J3=51
      J2=52
      GOTO10
   11 J3=50
      J2=51
      J1=52
      GOTO10
   14 IF(J2.GT.0) GOTO10
      IF(J2.EQ.-1) GOTO15
      J2=52
      GOTO10
   15 J2=51
      J1=52
      GOTO10
   13 IF(J1.EQ.0) J1=52
   10 TX=(3.1415926535898D0+RANU)**11
      ITXI=TX
      RANU=TX-FLOAT(ITXI)
      IFX1=RANU*50.
      II=IFX1+1
      EPSILO =INFISC (II)+(INFISC (II+1)-INFISC (II))*(RANU-PROB(II))/(P
     1ROB(II+1)-PROB(II))
C*****
C*****   ADD MARKOV DEPENDENCE OF SPECIFIED ORDER  NRDERI   WITH PERIODICITY
C*****
      IF(NRDERI .EQ.3) GOTO16
      IF(NRDERI .EQ.2) GOTO17
      Z=XYX1*CORRIN(1,J1)+EPSILO *RHOON(I)
      GOTO18
   17 Z=XYX1*CORRIN(1,J1)+XYX2*CORRIN(2,J2)+EPSILO *RHOON(I)
      GOTO18
   16 Z=XYX1*CORRIN(1,J1)+XYX2*CORRIN(2,J2)+XYX3*CORRIN(3,J3)+EPSILO *RH
     1OON(I)
C*****
```

```
C*****   ADD PERIODICITY IN THE MEAN AND STANDARD DEVIATION
C*****
   18 QI(K)=Z*TSDIN+TMFIN
      QI(K)=QI(K)*TSTDVI(I)+TMEANI(I)
C*****
C*****   CORRECT FOR NFGATIVE VALUES (SHOULD BE RARE)
      IF (QI(K).LT.0.)GO TO 10
C
C     ADJUSTMENT WITH HISTORICAL DATA
      QI(K)=QI(K)/1.6127
C*****
      XYX3=XYX2
      XYX2=XYX1
      XYX1=Z
  200 CONTINUE
 1000 CONTINUE
C
C     SEDIMENT INFLOW SERIES GENERATION
C
      DO 300 K=1,NN
      I=K-IFIX((FLOAT(K)-.5)/52.)*52
  310 TX=(3.1415926535898D0+RANU)**11
      ITXI=TX
      RANU=TX-FLOAT(ITXI)
      IFX1=RANU*50
      II=IFX1+1
      E=SEDISC (II)+(SEDISC (II+1)-SEDISC (II))*(RANU-PROB(II))/(PROB(II
     1+1)-PROB(II))
      QS(K)=E+.05467+.30735*((QI(K)-TMEANI(I))/TSTDVI(I))
      QS(K)=QS(K)*TSTDVS(I)+TMEANS(I)
      IF(QS(K).LT.0.)GO TO 310
C
C     ADJUSTMENT WITH HISTORICAL DATA
      QS(K)=QS(K)*1.35
  300 CONTINUE
C
C     EVAPORATION SERIES GENERATION
C
      DO 400 K=1,NN
      I=K-IFIX((FLOAT(K)-.5)/52.)*52
  410 TX=(3.1415926535898D0+RANU)**11
      ITXI=TX
      RANU=TX-FLOAT(ITXI)
      IFX1=RANU*50
      II=IFX1+1
      EATA=EVISCD(II)+(EVISCD(II+1)-EVISCD(II))*(RANU-PROB(II))/(PROB(II
     1+1)-PROB(II))
      QE(K)=EATA*TSTDVE(I)+TMEANE(I)
      IF(QE(K).LT.0.)GO TO 410
  400 CONTINUE
      RETURN
      END
```

```
C
C  ---------------------------------------------------------
C
      SUBROUTINE OPERAT
C
C  ---------------------------------------------------------
C
C     THIS SUBROUTINE DETERMINES RESERVOIR OUTFLOW,STORAGE,HEAD,POOL ELEVATION
C     AND SURFACE AREA, BASED ON OPERATION PLAN
C
      REAL IUSD(144),IMCD(144)
      DOUBLE PRECISION RANU,TX
      DIMENSION DHEAD(144),ELPREO(52)
      DIMENSION SPWT(2,520,3),ELEV(36),AREA(36),VOLUME(36),AAREA(36),AVO
     1L(36),V(520,36),X(520,3),AMPC(52),ASSL(2,2,3),XI(3),FP(520),HP(36)
      DIMENSION QI(520),QS(520),QE(520),PROB(51)
      COMMON/GENER/ELEV,AREA,VOLUME,NTI,HEAD,NTIYR,NUMBER,III,DAMHT
     1,ZELEV,AMPC,AVSTO
      COMMON ASSL,TT,SPWT,CPIFR,TE,BETA,EMM,ENN,ACQI,ACQS,NUOC,HH,V,IDS,
     1INS,AVOL,AAREA,X,GGAMA,XSAVE
      COMMON/GENERA/RANU,EPSILO,EATA,PROB,QI,QS,QE,QER,NN
      COMMON/SUBO/IUSD,IMCD,ELPREO,DHEAD,OUTFL
      COMMON/OPER/K,IM,RESUR,RESVOL
C*****
C*****
C*****     ELPREO(I)-RESERVOIR ELEVATION DURING WEEK#I,OF THE PRESENT OPERATION
C*****     TSTOR- TOTAL STORAGE
C*****     OUTFL-OUTFLOW
C*****     CHVOL-CHANGED RESERVOIR VOLUME
C*****     RESUR-RESERVOIR SURFACE AREA
C*****
C*****
      THEAD=ELPREO(52)
      B=650.
      K1=0
   20 K1=K1+1
      AA=ELEV(K1)
      IF(AA.GT.THEAD) GO TO 25
      B=AA
      GO TO 20
   25 CD=(THEAD-B)/(AA-B)
      K2=K1-1
      AVSTO=VOLUME(K2)+CD*(VOLUME(K1)-VOLUME(K2))
      DO 100 K=1,NN
      IM=K-IFIX((K-.5)/52.)*52
      TSTOR=QI(K)+AVSTO
      B=650.
      K1=0
   30 K1=K1+1
      AA=ELEV(K1)
      IF(AA.GT.ELPREO(IM)) GO TO 35
      B=AA
      GO TO 30
   35 CD=(ELPREO(IM)-B)/(AA-B)
      K2=K1-1
      VP=VOLUME(K2)+CD*(VOLUME(K1)-VOLUME(K2))
      EXSTOR=TSTOR-VP
      IF(EXSTOR.LE.0.) GO TO 40
```

```
      OUTFL=EXSTOR
      GO TO 45
   40 OUTFL=0.
   45 ATSTOR=(AVSTO+QI(K)-OUTFL+AVSTO)/2.
      B=0.
      K1=0
   46 K1=K1+1
      AA=VOLUME(K1)
      IF(AA.GT.ATSTOR)GO TO 47
      B=AA
      GO TO 46
   47 CD=(ATSTOR-B)/(AA-B)
      K2=K1-1
      AHEAD=ELEV(K2)+CD*(ELEV(K1)-ELEV(K2))
   80 B=0.
      K1=0
   83 K1=K1+1
      AA=DHEAD(K1)
      IF(AA.GT.AHEAD)GO TO 85
      B=AA
      GO TO 83
   85 CD=(AHEAD-B)/(AA-B)
      K2=K1-1
      SPILL=IUSD(K2)+CD*(IUSD(K1)-IUSD(K2))
      TDISCA=SPILL+IMCD(K2)+CD*(IMCD(K1)-IMCD(K2))
      IF(OUTFL.LE.TDISCA) GO TO 87
      OUTFL=OUTFL-1000.
      GO TO 45
   87 IF(OUTFL.GE.SPILL)  GO TO 97
      OUTFL=OUTFL+1000.
      GO TO 45
   97 CHVOL=TSTOR-OUTFL
      AVSTO=(AVSTO     +CHVOL)*.5
      B=0.
      K1=0
   60 K1=K1+1
      AA=VOLUME(K1)
      IF(AA.GT.AVSTO)GO TO 65
      B=AA
      GO TO 60
   65 CD=(AVSTO-B)/(AA-B)
      K2=K1-1
      RESUR=AREA(K2)+CD*(AREA(K1)-AREA(K2))
      CALL EVAPCO
      AVSTO=AVSTO-QER
      B=0.
      K1=0
   70 K1=K1+1
      AA=VOLUME(K1)
      IF(AA.GT.AVSTO)  GO TO 75
      B=AA
      GO TO 70
   75 CD=(AVSTO-B)/(AA-B)
      K2=K1-1
      HEAD=ELEV(K2)+CD*(ELEV(K1)-ELEV(K2))
      CALL SEDCOM
  100 CONTINUE
      RETURN

      END
```

```
C
C  -----------------------------------------------------------------
C
      SUBROUTINE EVAPCO
C
C  -----------------------------------------------------------------
C
      DOUBLE PRECISION RANU,TK
      DIMENSION QI(520),QS(520),QE(520),PROB(51)
      DIMENSION ELEV(36 ),AREA(36 ),AVOL(36 ),AMPC(52),VOLUME(36 )
      COMMON/GENER/ELEV,AREA,VOLUME,NTI,HEAD,NTIYR,NUMBER,III,DAMHT
     1,ZELEV,AMPC,AVSTO
      COMMON/GENERA/RANU,EPSILO,EATA,PROB,QI,QS,QE,QER,NN
      COMMON/OPER/K,IM,RESUR,RESVOL
C*****
C*****   THIS SUBROUTINE CALCULATES THE AMOUNT EVAPORATED IN A WEEK FROM
C*****   THE RESERVOIR
C*****
C*****   AMPC(I) - WEEKLY PAN EVAPORATION COEFFICIENTT FOR WEEK I
C*****
C*****
      QER=QE(IM)*RESUR*AMPC(IM)/12.
      RETURN
      END
```

```
C
C  -----------------------------------------------------------
C
      SUBROUTINE SEDCOM
C
C  -----------------------------------------------------------
C
C
C     THIS SUBROUTINE CALCULATES SEDIMENT VOLUMES TRAPPED IN THE RESERVOIR,
C     DISTRIBUTES THEM OVER THE HEIGHT,COMPACTS THEM AT SPECIFIED INTERVALS
C     AND APPLY NECESSARY CORRECTIONS FOR SEDIMENT SLUMP
C
C
      REAL IUSD(144),IMCD(144)
      DOUBLE PRECISION RANU,TX
      DIMENSION SPWT(2,520,3),ELEV(36),AREA(36),VOLUME(36),AAREA(36),AVO
     1L(36),V(520,36),X(520,3),AMPC(52),ASSL(2,2,3),XI(3),FP(520),HP(36)
      DIMENSION ASNL(2,2,3),P(3,3)
      DIMENSION DHEAD(144),ELPREO(52)
      DIMENSION QI(520),QS(520),QE(520),PROB(51)
      DIMENSION W(50),IK2(50)
      COMMON ASSL,TT,SPWT,CPIFR,TE,BETA,EMM,ENN,ACQI,ACQS,NUOC,HH,V,IDSS
     1,INS,AVOL,AAREA,X,GGAMA,XSAVE,DELTA
      COMMON/GENER/ELEV,AREA,VOLUME,NTI,HEAD,NTIYR,NUMBER,III,DAMHT
     1,ZELEV,AMPC,AVSTO
      COMMON/GENERA/RANU,EPSILO,EATA,PROB,QI,QS,QE,QER,NN
      COMMON/SUBO/IUSD,IMCD,ELPREO,DHEAD,OUTFL
      COMMON/OPER/K,IM,RESUR,RESVOL
      COMMON/SUBOPE/XI,X1,X2,X3
C*****
C*****
C*****   SPWT(K,I,J) - DENSITY OF SEDIMENT IN LEVEL K AND ZONE J,  I YEARS OLD
C*****   ASSL(K,I,J) - DENSITY (I=1) OR COMPACTION COEFFICIENT (I=2) OF
C*****   SEDIMENT IN LEVEL K IN ZONE J
C*****   ELEV - ELEVATION FOR STAGE-AREA AND STAGE-VOLUME RELATIONS OF RESERVOIR
C*****   AREA - AREA FOR ELEVATION-AREA RELATION OF RESERVOIR
C*****   VOLUME - VOLUME FOR ELEVATION-VOLUME RELATION OF RESERVOIR
C*****   AAREA - ORIGINAL AREA FOR ELEVATION-AREA RELATION OF RESERVOIR
C*****   AVOL - ORIGINAL VOLUME FOR ELEVATION-VOLUME RELATION OF RESERVOIR
C*****   NOTE: THE ORIGINAL ELEVATION-VOLUME RELATIONSHIP MUST SATISFY THE
C*****         FOLLOWING RELATIONSHIP TO BE PHYSICALLY MEANINGFUL,(AVOL(J+1)-
C*****         AVOL(J))/(ELEV(J+1)-ELEV(J)).GT.(AVOL(J)-AVOL(J-1))/(ELEV(J)-
C*****         ELEV(J-1)) FOR ALL J. IF THIS IS NOT TRUE FOR THE INPUT(ORIGINAL)
C*****         RELATIONSHIP BECAUSE OF MEASUREMENT OR NUMERICAL(ROUND-OFF)
C*****         ERRORS, THEN THE RELATIONSHIP MUST BE ADJUSTED AT LEAST UNTIL
C*****         THE ABOVE IS TRUE. FAILURE TO DO SO MAY LEAD TO INFEASIBLE SEDI-
C*****         MENT ALLOCATIONS IN THIS MODEL.
C*****   FP,W,IK2, AND HP - ARRAYS USED FOR TEMPORARY STORAGE IN VARIOUS
C*****   CALCULATIONS.  FP MUST BE DIMENSIONED AS HP OR AS ELEV, WHICHEVER IS OF
C*****   GREATER DIMENSION
C*****   V(I,J) - ARRAY OF UNCOMPACTED OR COMPACTED SEDIMENT VOLUME OF TIME I AT
C*****   POSITION J IN THE RESERVOIR
C*****   NTI - NUMBER OF TIME INTERVALS IN VOLUME-AREA CORRECTION PERIOD
C*****   EMM,ENN - COEFFICIENTS IN TYPE EQUATIONS FOR RESERVOIR FROM PREVIOUS
C*****   EMPIRICAL WORK
C*****   BETA - TRIAL AND INCREMENT FRACTION OF TRAPPED SEDIMENT THAT COMPLETELY
C*****   FILLS THE RESERVOIR TO THE NEW ZERO ELEVATION
C
```

```
      IF(((K/NTI)*NTI).EQ.K)GOTO10
C
C*****    DEAVOL - VOLUME OF SEDIMENT BELOW ZERO ELEVATION
C*****    X(I) - FRACTION OF INCOMING SEDIMENT THAT IS COMPONENT I (AFTER
C*****    SLUICING),I=1 FOR CLAY,I=2 FOR SILT,I=3 FOR SAND
C*****    ACQI - ACCUMULATED INFLOW IN CORRECTION PERIOD
C*****    ACQS - ACCUMULATED SEDIMENT INFLOW IN CORRECTION PERIOD
C*****    NUOC - NUMBER OF VOLUME-AREA CORRECTION PERIOD
C*****    HEAD - HEAD IN RESERVOIR DURING TIME INCREMENT (ABOVE ZERO-ELEVATION)
C*****    HH - AVERAGE HEAD IN RESERVOIR DURING CORRECTION PERIOD
C*****    NTIYR - NUMBER OF TIME INTERVALS IN A YEAR
C*****    IDS - SUBSCRIPT OF WATER LINE ELEVATION USED IN DELINEATING THE
C*****    UPPER AND LOWER DENSITIES
C*****    NUMBER - NUMBER OF ENTRIES IN ELEVATION-AREA-VOLUME ARRAY
C*****    GAMMA(I) - DENSITY OF INCOMING SEDIMENT COMPONENT I
C*****    GGAMA - OVERALL DENSITY OF INCOMING SEDIMENT
C*****    ZELEV - ZERO ELEVATION OF SEDIMENT AT THE DAM
C*****    DAMHT - HEIGHT OF DAM USED IN CALCULATING CAPACITY OF RESERVOIR
C*****
C*****    ACCUMULATING ENTRIES IN INTERIM OF CORRECTION PERIODS
C*****
      ACQI=ACQI+OUTFL
      ACQS=ACQS+QS(K)
      RESVOL=RESVOL+AVSTO
      HH=HH+HEAD-ZELEV
      RETURN
C*****
C*****    INCREMENT NUMBER OF CORRECTION PERIOD
C*****
   10 NUOC=NUOC+1
C*****
C*****    DETERMINATION OF ESTIMATED VOLUME OF SEDIMENT TRAPPED AT THE END
C*****    OF THE CORRECTION PERIOD
C*****
      ACQI=ACQI+OUTFL
      ACQS=ACQS+QS(K)
      RESVOL=RESVOL+AVSTO
      HH=HH+HEAD-ZELEV
      HH=HH/FLOAT(NTI)
      EVT=-.11718*ACQI+.02153*RESVOL+.988*ACQS+111.68*NTI
      IF(EVT.GT.ACQS) EVT=ACQS
      IF(EVT.LT.0.) EVT=0.
      EVT=EVT+XSAVE
      YR=FLOAT(NTI)/FLOAT(NTIYR)*(FLOAT(NUOC)-.5)
      IF(YR.LT.1.0) YR=1.0
      AVPOOL=HH+ZELEV
      WRITE(6,901)
      WRITE(6,903)
      WRITE(6,910) HH,AVPOOL,OUTFL,ACQS,RESVOL,EVT
901   FORMAT(///,100('*'),///)
903   FORMAT(//,5X,'HH,AVPOOL  ARE IN FT.',/,5X,'OUTFL,RESVOL  ARE IN AC
     *RE-FT.',/,5X,'ACQS, EVT  ARE IN  TONS',//)
  910 FORMAT(5X,'HH = ',F7.1,5X,'AVPOOL = ',F8.1,3X,'OUTFL=',F8.1,3X,'AC
     *QS=',F14.1,3X,/,5X,'RESVOL=',F14.1,3X,'EVT=',F14.1)
C*****
C*****    DETERMINATION OF DENSITIES OF AGED SEDIMENT COMPONENTS
C*****
      YR=ALOG10(YR)
```

```
      DO80I=1,2
      DO80J=1,3
   80 SPWT(I,NUOC,J)=1.+ASSL(I,2,J)*YR/ASSL(I,1,J)
      IF(EVT.LT.10.) GO TO 5000
      EVT=EVT*2000./(GGAMA*43560.)
      XSAVE=0.
C*****
C*****    DETERMINATION OF NEW ZERO ELEVATION
C*****
      I=0
   31 I=I+1
      IF(ELEV(I).GT.ZELEV)GOTO30
      GOTO31
   30 II=I-1
   13 II=II+1
      IF((ELEV(II)-ZELEV).GT.HH)GOTO14
      S=(ELEV(II)-ZELEV)/HH
      FP(II)=S**EMM*(1.-S)**ENN
      GOTO13
   14 IF((ELEV(II-1)-ZELEV).EQ.HH)GOTO15
      FP(II)=0.
      II=II+1
   15 II=II-1
      IJ=II-1
      OZELEV=ZELEV
C*****
C*****    INTERPOLATION AND DETERMINATION OF ZERO ELEVATION
C*****
      DEAVOL=BETA*EVT
   99 K1=0
   16 K1=K1+1
      AA=VOLUME(K1)
      IF(AA.GT.DEAVOL)GOTO18
      B=AA
      GOTO16
   18 K2=K1-1
      IF(B.GT.0.)GOTO19
      AA=(AREA(K1)-TT)/(ELEV(K1)-OZELEV)
      ZELEV=OZELEV+(SQRT(TT**2+2*DEAVOL*AA)-TT)/(AA)
      CD=(ZELEV-OZELEV)/(ELEV(K1)-OZELEV)
      GOTO20
   19 AA=(AREA(K1)-AREA(K2))/(ELEV(K1)-ELEV(K2))
      ZELEV=ELEV(K2)+(SQRT(AREA(K2)**2+2*(DEAVOL-B)*AA)-AREA(K2))/(AA)
      CD=(ZELEV-ELEV(K2))/(ELEV(K1)-ELEV(K2))
   20 FPO=ZELEV-OZELEV
C*****
C     CALCULATION OF RELATIVE AND ACTUAL RESERVOIR AREA AT ZERO ELEVATION
C*****
      FKA=(FPO/HH)**EMM*(1.-FPO/HH)**ENN
      IF(FKA.LT.0.00001) GO TO 97
      IF(B.GT.0.)GOTO96
      AZS=TT+CD*(AREA(K1)-TT)
      GOTO101
   96 AZS=AREA(K2)+CD*(AREA(K1)-AREA(K2))
  101 AZSS=AZS
C*****
C     CALCULATION OF RELATIVE SEDIMENT AREAS
C*****
```

```
C
C      HP(J) REPRESENTS SEDIMENT AREAS AT ELEV.INDEX J IN THIS PART OF PROGRAM
   17 S=0.
      DO22J=K1,II
   22 HP(J)=AZSS*FP(J)/FKA
C*****
C*****     DISTRIBUTION OF SEDIMENT ALONG THE RESERVOIR HEIGHT
C*****
      IF(K2.LT.I)GO TO 400
      DO 401 J=2,I
  401 V(NUOC,J-1)=0.
      DO24J=I,K2
      V(NUOC,J-1)=VOLUME(J)-VOLUME(J-1)
   24 S=S+V(NUOC,J-1)
      GO TO 34
  400 IF(K2.EQ.1) GO TO 34
      DO 402 J=2,K2
  402 V(NUOC,J-1)=0.
   34 B=(ELEV(K1)-ZELEV)*(AZSS+HP(K1))/2.
      IF(B.GT.(VOLUME(K1)-DEAVOL)) B=VOLUME(K1)-DEAVOL
      V(NUOC,K2)=DEAVOL-VOLUME(K2)+B
      S=S+V(NUOC,K2)
      DO25J=K1,IJ
      V(NUOC,J)=(ELEV(J+1)-ELEV(J))*(HP(J)+HP(J+1))/2.
   25 S=S+V(NUOC,J)
      IF((ABS(S-EVT)/EVT).LE.0.01) GO TO 98
C
C      MODIFICATION OF ZERO ELEVATION RESERVOIR AREA
      AZSS=(EVT-DEAVOL)/(S-DEAVOL)*AZSS
      IF(AZSS.GT.AZS)GOTO97
      IF(AZSS.GT.0.) GO TO 17
      II=K1
      GO TO 98
   97 DEAVOL=DEAVOL+BETA*EVT
      GOTO99
   98 IF(EVT.GE.(S*0.9999)) EVT=S*0.9999
C
C      HP(J) REPRESENTS COMPACTED SEDIMENT VOLUMES BETWEEN ELEV.INDICES
C       J AND J+1 IN THE REMAINING PART OF THE PROGRAM
C
      DO 26J=1,IJ
   26 HP(J)=0.
      DO 403 J=II,III
      HP(J)=0.
  403 V(NUOC,J)=0.
C*****
C*****     SEPERATION OF SEDIMENT IN RESERVOIR (DIFFERENTIAL SETTLING)
C*****
      AA=0.
      K1=0
      B=0.
      YYY=0.
      DO 61 J=1,3
      YYY=XI(J)*EVT+YYY
   62 K1=K1+1
      AA=V(NUOC,K1)+AA
      IF(AA.GT.YYY)GO TO 63
      B=AA
```

```
      GO TO 62
   63 X(NUOC,J)=FLOAT(K1)+(YYY-B)/(AA-B)
      IF(YYY.EQ.B)X(NUOC,J)=X(NUOC,J)-.0001
      AA=AA-V(NUOC,K1)
   61 K1=K1-1
C
C     USVOL= UNCOMPACTED SEDIMENT VOLUME BETWEEN ELEV.INDICES K2 AND K2+1
      USVOL=0
      DO 40 KK=1,NUOC
40    USVOL=USVOL+V(KK,K2)
C*****
C*****   COMPACTION OF SEDIMENT AT EACH ELEVATION WITH RESPECT TO THE DENSITIES
C*****   AS FUNCTIONS OF MATERIAL,AGE,AND SUBMERGENCE
C*****
      IDS=III
      DO 3028 KK=1,NUOC
      IF(X(KK,1).EQ.0.) GO TO 3028
      NREC=NUOC+1-KK
      IJI=IFIX(X(KK,1))
      IJ2=IFIX(X(KK,2))
      IJ3=IFIX(X(KK,3))
      AA=0.
      HH=0.
      YYY=0.
      JI=1
      J=0
   71 J=J+1
      A=V(KK,J)
      IF(J.EQ.IDS)JI=2
      IF(J.EQ.IJI) GO TO 70
      R=A/SPWT(JI,NREC,1)
      V(KK,J)=R
      HP(J)=HP(J)+R
      AA=AA+R
      HH=HH+R
      YYY=YYY+R
      GO TO 71
   70 IF(J.EQ.IJ2) GO TO 72
      B=A*(X(KK,1)-FLOAT(J))/SPWT(JI,NREC,1)
      R=B+A*(FLOAT(J+1)-X(KK,1))/SPWT(JI,NREC,2)
      V(KK,J)=R
      HP(J)=HP(J)+R
      AA=AA+B
      HH=HH+R
      YYY=YYY+R
      GOTO74
   72 B=A*(X(KK,1)-FLOAT(J))/SPWT(JI,NREC,1)
      S =A*(X(KK,2)-X(KK,1))/SPWT(JI,NREC,2)
      R=B+S +A*(FLOAT(J+1)-X(KK,2))/SPWT(JI,NREC,3)
      V(KK,J)=R
      HP(J)=HP(J)+R
      AA=AA+B
      HH=HH+B+S
      YYY=YYY+R
      IF(J.EQ.IJ3) GO TO 28
      GOTO75
   74 J=J+1
      A=V(KK,J)
```

```
      IF(J.EQ.IDS)JI=2
      IF(J.EQ.IJ2)GOTO82
      R=A/SPWT(JI,NREC,2)
      V(KK,J)=R
      HP(J)=HP(J)+R
      HH=HH+R
      YYY=YYY+R
      GOTO74
   82 B=A*(X(KK,2)-FLOAT(J))/SPWT(JI,NREC,2)
      R=B+A*(FLOAT(J+1)-X(KK,2))/SPWT(JI,NREC,3)
      V(KK,J)=R
      HP(J)=HP(J)+R
      HH=HH+B
      YYY=YYY+R
      IF(J.EQ.IJ3) GO TO 28
   75 J=J+1
      A=V(KK,J)
      IF(J.EQ.IDS)JI=2
      IF(J.GT.IJ3)GOTO28
      R=A/SPWT(JI,NREC,3)
      V(KK,J)=R
      HP(J)=HP(J)+R
      YYY=YYY+R
      GOTO75
   28 X(KK,1)=AA
      X(KK,2)=HH
      X(KK,3)=YYY
 3028 IDS=IDSS
C*****
C*****   CORRECTION TO ZERO ELEVATION FOR COMPACTION OF SEDIMENT
C*****
      IIK2=K2
      S=0.
      B=0.
      DO 301 J=1,K2
  301 S=S+HP(J)
300   DEAVOL=S-HP(K2)+(ZELEV-ELEV(K2))/(ELEV(K2+1)-ELEV(K2))*(AVOL(K2+1)
     *-AVOL(K2))*(HP(K2)/USVOL)
   33 K1=0
   35 K1=K1+1
      AA=AVOL(K1)
      IF(AA.GT.DEAVOL)GOTO36
      B=AA
      GOTO35
   36 CD=(DEAVOL-B)/(AA-B)
      K2=K1-1
      ZELEV=ELEV(K2)+CD*(ELEV(K1)-ELEV(K2))
C*****
C*****   SEDIMENT SLUMP TO CORRECT ANOMALY INDUCED BY COMPACTION AT ZERO
C*****   ELEVATION
C*****
      IF(K2.EQ.IIK2)GO TO 90
  472 SSS=0.
      DO 460 I=1,IIK2
  460 SSS=SSS+HP(I)
      SSS=SSS-DEAVOL
      RRR=AVOL(IIK2+1)-DEAVOL
      HP(K2)=SSS/RRR*(AVOL(K1)-DEAVOL)+DEAVOL-AVOL(K2)
```

AD-A058 688 IOWA INST OF HYDRAULIC RESEARCH IOWA CITY F/G 13/2
RESERVOIR SEDIMENTATION MODEL WITH CONTINUING DISTRIBUTION, COM--ETC(U)
JUN 78 T E CROLEY, K N RAO, F KARIM

UNCLASSIFIED IIHR-198 NL

2 OF 2

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```
      AREA(K1)=(AVOL(K1)-AVOL(K2)-HP(K2))/(ELEV(K1)-ZELEV)
      KPI=K2+1
      DO 470J=KPI,IIK2
      HP(J)=SSS/RRR*(AVOL(J+1)-AVOL(J))
  470 AREA(J+1)=(AVOL(J+1)-AVOL(J)-HP(J))/(ELEV(J+1)-ELEV(J))
      IF(AREA(IIK2+1).GE.AREA(IIK2)) GO TO 94
      IIK2=IIK2+1
      GO TO 472
   90 HP(K2)=S-B
      AREA(K1)=(AVOL(K1)-AVOL(K2)-HP(K2))/(ELEV(K1)-ZELEV)
      KPI=K1+1
      AREA(KPI)=(AVOL(KPI)-AVOL(K1)-HP(K1))/(ELEV(KPI)-ELEV(K1))
      IF(AREA(KPI).GE.AREA(K1)) GO TO 94
      IIK2=IIK2+1
      GO TO 472
   94 IF(K2.EQ.1)GO TO 95
      IIK2=K2-1
      DO 93 J=1,IIK2
   93 HP(J)=AVOL(J+1)-AVOL(J)
C*****
C*****   ADJUSTMENT TO ELEVATION-AREA-VOLUME RELATION BECAUSE OF SEDIMENT
C*****
   95 DO37J=1,K2
      AREA(J)=0.
   37 VOLUME(J)=0.
      AA=AVOL(K2)+HP(K2)
      K2=K2+1
      VOLUME(K2)=AVOL(K2)-AA
      K2=K2+1
  630 DO38J=K2,NUMBER
      AA=AA+HP(J-1)
      VOLUME(J)=AVOL(J)-AA
      AREA(J)=(VOLUME(J)-VOLUME(J-1))/(ELEV(J)-ELEV(J-1))
      IF(AREA(J).GT.AREA(J-1)) GO TO 38
      GO TO 666
   38 CONTINUE
      GO TO 640
C*****
C*****   SEDIMENT SLUMP TO CORRECT ANOMALY INDUCED BY COMPACTION AT SEDIMENT
C*****   ZONE INTERFACES
C*****
  666 KY=J-1
      AA=AA-HP(KY)-HP(KY-1)
  669 BB=AA
      SSS=0.
      DO 667 I=KY,J
  667 SSS=SSS+HP(I-1)
      RRR=AVOL(J)-AVOL(KY-1)
      DO 668 I=KY,J
      HP(I-1)=SSS/RRR*(AVOL(I)-AVOL(I-1))
      BB=BB+HP(I-1)
      VOLUME(I)=AVOL(I)-BB
  668 AREA(I)=(VOLUME(I)-VOLUME(I-1))/(ELEV(I)-ELEV(I-1))
      J=J+1
      IF(AREA(J).LE.AREA(J-1)) GO TO 669
      IF(AREA(KY).LE.AREA(KY-1)) GO TO 670
      AA=BB
      K2=J
```

```
      GO TO 630
  670 J=J-1
      KY=KY-1
      AA=AA-HP(KY-1)
      GO TO 669
  640 A=(ELEV(K1)-ZELEV)/(ELEV(K1+1)-ZELEV)*(AREA(K1+1)-AREA(K1))+AREA(K
     11)
      TT=2.*AREA(K1)-A
      IF(TT.LT.0)TT=0
      IF(TT.EQ.0.)ZELEV=ELEV(K1)-2.*VOLUME(K1)/A
      AREA(K1)=A
      K1=K1+1
      DO 900 J=K1,III
  900 AREA(J)=(ELEV(J)-ELEV(J-1))/(ELEV(J+1)-ELEV(J-1))*(AREA(J+1)-AREA(
     1J))+AREA(J)
      AREA(NUMBER)=2.*AREA(NUMBER)-AREA(III)
C*****
C*****   COMPACTED SEDIMENT OF EACH AGE IS REDISTRIBUTED (SLUMPS) TO AGREE WITH
C*****   ACCUMULATED (OVER ALL AGES) SEDIMENT DISTRIBUTION
C*****
      DO999KK=1,NUOC
  999 FP(KK)=0.
C
C     CALCULATION OF EXCESS SEDIMENT VOLUMES AND IDENTIFICATION OF
C     THEIR LOCATIONS(IN TERMS OF AGES)
C
      DO 1000 J=1,III
      IK2(J)=0
      S=0.
      KK=NUOC
 1003 IF(V(KK,J).GT.0.) GO TO 1002
      KK=KK-1
      IF(KK.EQ.0) GO TO 1000
      GO TO 1003
 1002 DO 1007 I=1,KK
 1007 S=S+V(I,J)
      SS=ABS(S-HP(J))
      IF(SS.LT.DELTA) GO TO 1000
 1001 IF(S.LT.HP(J)) GO TO 1004
      S=HP(J)/S
      DO 1005 I=1,KK
      A=V(I,J)*S
      FP(I)=FP(I)+V(I,J)-A
 1005 V(I,J)=A
      GO TO 1000
 1004 IK2(J)=KK
      W(J)=S
 1000 CONTINUE
C
C     REDISTRIBUTION OF EXCESS SEDIMENT VOLUMES BY PROPORTIONATELY INCREASING
C     SEDIMENT VOLUMES OF ALL AGES BETWEEN EACH PAIR OF ELEV.INDICES
C     WHERE DEFICIT EXISTS
C
      DO 1006 J=1,III
      KK=IK2(J)
      IF(KK.EQ.0)GOTO1006
      R=W(J)
      B=HP(J)
```

```
      B1=B
      RR=B-R
      IF(RR.LT.DELTA) GO TO 1006
C
C     REDISTRIBUTION STARTING FROM OLDEST TO LATEST SEDIMENTS
C
      DO 1008 I=1,KK
      S=V(I,J)
      A=S*B1/R-S
      IF(A.GT.FP(I))A=FP(I)
      FP(I)=FP(I)-A
      A=A+S
      V(I,J)=A
      B=B-A
      IF(B.LT.DELTA) GO TO 1006
1008  CONTINUE
      IF(B.LT.DELTA) GO TO 1006
C
C     REDISTRIBUTION OF REMAINING EXCESS SEDIMENT VOLUMES STARTING
C     FROM LATEST TO OLDEST SEDIMENTS
C
      DO 1009 L=1,KK
      R=B
      I=KK+1-L
      IF(R.GT.FP(I))R=FP(I)
      V(I,J)=V(I,J)+R
      FP(I)=FP(I)-R
      B=B-R
      IF(B.LT.DELTA) GO TO 1006
1009  CONTINUE
      IF(KK.EQ.NUOC) GO TO 1006
      IF(B.LT.DELTA) GO TO 1006
      KK=KK+1
C
C     REDISTRIBUTION OF STILL REMAINING EXCESS SEDIMENT VOLUMES TO
C     LOCATIONS(OR AGES) WHERE NO DEPOSITION OCCURRED PREVIOUSLY
C
      DO 1010 I=KK,NUOC
      R=B
      IF(R.GT.FP(I))R=FP(I)
      V(I,J)=R
      FP(I)=FP(I)-R
      B=B-R
      IF(B.LT.DELTA) GO TO 1006
1010  CONTINUE
 1006 CONTINUE
C
C     RECOMPUTATION OF ELEV.INDICES AT SEDIMENT ZONE INTERFACES RESULTING
C     FROM REDISTRIBUTION OF SEDIMENT FOR SLUMP
C
      DO 3061 KK=1,NUOC
      IF(X(KK,1).EQ.0.) GO TO 3061
      IFLAG=0
      AA=0.
      K2=0
      B=0.
      DO 3060 J=1,3
      YYY=X(KK,J)
```

```
3062 IF(K2.EQ.III) GO TO 4000
     K2=K2+1
     IF(V(KK,K2).EQ.0.) GO TO 3007
     IF(K2.LT.III) GO TO 3003
     IFLAG=1
     GO TO 3001
3003 IF(V(KK,K2+1).EQ.0.)IFLAG=1
3001 AA=V(KK,K2)+AA
     IF(AA.GT.YYY) GO TO 3063
     B=AA
3007 IF(IFLAG.EQ.0) GO TO 3062
4000 X(KK,J)=FLOAT(K2)+.9999
     GO TO 4001
3063 X(KK,J)=FLOAT(K2)+(YYY-B)/(AA-B)
     IF(YYY.EQ.B)X(KK,J)=X(KK,J)-0.0001
4001 AA=AA-V(KK,K2)
3060 K2=K2-1
3061 CONTINUE
     IFLAG=0
2038 CONTINUE
C
C    PRINTING OF OUTPUT RESULTS
C
     IF((K/NTIYR)*NTIYR.NE.K) GO TO 2500
     WRITE(6,602)
     IY=K/NTIYR
     WRITE(6,605)IY
 605 FORMAT(24X,'ELEVATION-VOLUME-AREA RELATION AFTER ',I5,' YEARS OF
    1 SEDIMENTATION'//3 X,'ELEVATION',4X,'SEDIMENT VOLUMES(ACRE-FT)',
    *35X,'VOLUME',3X,'AREA'/3X,'(FT,MSL)', 65X,'(AFT)',3X,'(ACRES)',/)
     K2=K1-2
     DO 9000 J=1,K2
     WRITE(6,600)ELEV(J),VOLUME(J),AREA(J)
9000 WRITE(6,601) (V(KK,J),KK=1,NUOC)
     WRITE(6,603)ZELEV,VOLUME(K2),TT
     K2=K2+1
     DO 9001 J=K2,III
     WRITE(6,600)ELEV(J),VOLUME(J),AREA(J)
9001 WRITE(6,601) (V(KK,J),KK=1,NUOC)
     WRITE(6,600)ELEV(NUMBER),VOLUME(NUMBER),AREA(NUMBER)
     WRITE(6,602)
600  FORMAT(5X,F4.0, 61X,F10.2,3X,F9.2)
 601 FORMAT(10X, 6F10.2)
602  FORMAT(///)
603  FORMAT(5X,F6.2,'(ZERO ELEVATION)',43X,F10.2,3X,F9.2)
 2500 CONTINUE
     IF(IFLAG.EQ.1) GO TO 5003
C*****
C*****  UNCOMPACTED SEDIMENT EQUIVALENT OF EACH AGE IS CALCULATED FROM
C*****  REDISTRIBUTED COMPACTED SEDIMENT (NEWLY WETTED SEDIMENT OF EACH AGE
C*****  CONTINUES COMPACTION WITH WET ZONE COEFFICIENTS AT SAME AGE)
C*****
     DO 2028 KK=1,NUOC
     IF(X(KK,1).EQ.0.) GO TO 2028
     NREC=NUOC+1-KK
     IJ1=IFIX(X(KK,1))
     IJ2=IFIX(X(KK,2))
     IJ3=IFIX(X(KK,3))
```

```
      JI=1
      J=0
 2071 J=J+1
      A=V(KK,J)
      IF(J.EQ.IDS)JI=2
      IF(J.EQ.IJ1) GO TO 2070
      V(KK,J)=A*SPWT(JI,NREC,1)
      GO TO 2071
 2070 IF(J.EQ.IJ2) GO TO 2072
      B=A*(X(KK,1)-FLOAT(J))*SPWT(JI,NREC,1)
      R=B+A*(FLOAT(J+1)-X(KK,1))*SPWT(JI,NREC,2)
      V(KK,J)=R
      X(KK,1)=FLOAT(J)+B/R
      GO TO 2074
 2072 B=A*(X(KK,1)-FLOAT(J))*SPWT(JI,NREC,1)
      S=A*(X(KK,2)-X(KK,1))*SPWT(JI,NREC,2)
      R=B+S+A*(FLOAT(J+1)-X(KK,2))*SPWT(JI,NREC,3)
      V(KK,J)=R
      X(KK,1)=FLOAT(J)+B/R
      X(KK,2)=FLOAT(J)+(B+S)/R
      X(KK,3)=FLOAT(J)+0.9999
      IF(J.EQ.IJ3) GO TO 2028
      GO TO 2075
 2074 J=J+1
      A=V(KK,J)
      IF(J.EQ.IDS)JI=2
      IF(J.EQ.IJ2) GO TO 2082
      V(KK,J)=A*SPWT(JI,NREC,2)
      GO TO 2074
 2082 B=A*(X(KK,2)-FLOAT(J))*SPWT(JI,NREC,2)
      R=B+A*(FLOAT(J+1)-X(KK,2))*SPWT(JI,NREC,3)
      V(KK,J)=R
      X(KK,2)=FLOAT(J)+B/R
      X(KK,3)=FLOAT(J)+0.9999
      IF(J.EQ.IJ3) GO TO 2028
 2075 J=J+1
      A=V(KK,J)
      IF(J.EQ.IDS)JI=2
      IF(J.GT.IJ3) GO TO 2028
      V(KK,J)=A*SPWT(JI,NREC,3)
      X(KK,3)=FLOAT(J)+0.9999
      GO TO 2075
 2028 CONTINUE
C*****
C*****   REINITIALIZATION OF PARAMETERS
C*****
 5003 ACQI=0.
      ACQS=0.
      HH=0.
      RESVOL=0.
      RETURN
 5000 DO 5001 J=1,III
 5001 V(NUOC,J)=0.
      XSAVE=EVT
      DO 5002 J=1,3
 5002 X(NUOC,J)=0.
      IFLAG=1
      GO TO 2038
      END
```

```
//GO.SYSIN DD *
 1
 10
.000025
 32072.7 23206.6 17742.1 15796.3 28780.1 12670.4 56661.8 42307.4 14068.7




  9629.7  6791.4  8759.0  6240.0  4990.4  4437.0  4133.6  3824.1 15736.8
  7414.2  4661.2  4185.1  3173.6  2796.7  3887.6  2955.4  2687.6  1993.4
  2043.0  1884.3  1963.6  2459.5 28661.1 53395.0 29137.2 91140.4156535.4
113613.1 40621.5 23682.6 25904.1 41871.0 26042.9 30644.6 52978.5 45064.4
 54545.4 31200.0 14360.3  9592.1 36924.3 22869.4 13590.7  9488.9  7083.0
  6291.6  5293.9  4724.6  3504.8  4026.4  6487.9  3373.9  3161.6  8953.4
  8441.6  5615.2  4843.6  5166.9 21001.0 18446.3 12872.7 13745.4 12545.4
 10389.4  9431.4  8876.0 20945.4 12813.2 99371.8 37487.6 27768.6 16879.3
 13904.1 11821.5 12158.7  9758.7  7715.7  7398.3  8350.4188429.6169427.9
 61943.8 80727.1 46809.9 72833.0147689.0 64740.4 65890.8 64264.4 33381.8
 27609.9 27094.2 17950.4 14033.0 23047.9 13225.8 10899.2  7358.7  6293.5
  5601.3  5720.3  7666.1  4901.1  3453.2  4835.7 16681.0  8604.3  6372.9
  5438.7  5262.1 14632.0  8737.2  7804.9  6628.8  5256.2  4919.0  4443.0
  3312.4  3669.4  3590.1  3421.5  3600.0  2320.7  1795.0  2052.9 16462.8
 69421.4 46393.4103993.2 95642.8 66426.4 64998.3 71761.9 36238.0 36099.1
 35127.2 23127.2 17514.0 15173.5 13388.4 11609.2 31418.2 21104.1 13646.3
  9233.0  9873.7  7959.7 11504.1 15139.8 25824.8 19804.9  9467.1  6420.5
  4536.2  4105.8 20013.2  9998.7  7876.4 32568.6 21520.6 23008.2 16581.8
 31477.7 34651.2 40938.8 43279.3 31239.6 24495.8 18089.2 19438.0 16462.8
 15471.1 12515.7 10988.4  9084.3  9758.7 14577.7 18049.6 14251.1 12039.7
 11781.8 23008.2102842.9184661.0145586.6 98459.4 64403.3 38419.8 30109.1
 38737.2 39927.2 24376.8 59246.2 51312.4 37328.9 20449.6 15332.2 15619.8
 31715.7123966.7 97864.3 40185.1 24119.0 15719.0 12803.3 11085.6 21179.5
 27034.7 14290.9  9903.5 11525.9 14608.2  4425.1  2465.5 10310.1 12083.3
  9540.5  8429.7  7715.7  7239.7  6470.1  5942.5  3455.2  1493.6  1511.4
  3788.4  4284.3  4066.1  4502.5  3748.8  3371.9  2578.5  4304.1  6406.6
  7676.0  6208.3 26935.5 53355.3566478.8151100.6 26538.8 15679.3 11563.6
 12065.4 23095.5 39649.6 33123.9 30604.9 16938.8 14390.1 17153.0 16710.7
 10155.4  9318.3 13785.1 22452.9 31557.0 17976.2 12376.8 10690.9  6311.4
  5430.7  5611.2  4706.8  4046.3  3808.3  3314.4  2929.6  2671.7  3024.8
  2778.8  2645.9  2596.4  2602.3  3518.7  2893.9  2338.5  1725.6  1088.9
  1069.1  1106.8  1342.8  1553.1  2465.5  2479.3  2727.3  2856.2  2782.8
  2824.5  3145.8  4476.7  3824.1  3215.2 13023.5 10919.0 10857.5 13487.6
 18922.3 23444.6 19517.3 14386.1 10450.9  7154.4 13622.5 43219.8 19989.4
 14515.0 18981.8 14027.1  7102.8  9933.2  6765.6  4260.5  3901.5  6573.2
  8217.5 11042.0 13916.0  8638.0  5793.7  4770.2  4256.5  3905.5  3909.4
  3530.6  3477.0  2489.3  2469.4  2390.1  3451.2  2320.7  2102.5 10076.0
  4581.8  3054.5 26281.0  3252.9 43338.8 25983.4 26578.5 45024.8 55933.8
 46016.5 39669.4 73983.4219173.3204098.9108297.4 83087.5 37626.4 23682.6
 16542.1 23444.6 57699.1 61943.8 31418.1 19081.0 18636.7 22552.0 48158.6
 21500.8 11700.5  7586.8  6041.6  4585.8  4899.2 15276.7 19537.2 40343.8
 72138.8107960.1102346.9 67933.8 33699.1 37725.6 26995.0 21937.2 28720.6
 23008.2 20112.4 19180.1 23444.6 27927.2 28859.5 32548.7 28452.8 21223.1
 13249.6  8826.4 33203.3 37487.6 18981.8 15094.2 16700.8 16452.8 39847.9
 42545.4 36833.0 30565.3 27332.2 24436.3 22750.4 24952.0 60555.3 58909.0
 52720.6 33917.3112482.5100006.4 38380.1 31636.3 20271.1 15740.8 16684.9
 12799.3  8640.0  6944.1  8604.3  6585.1  4401.3  3691.2  3203.3  2731.2
  2647.9  2596.4  3310.4  2463.5  2179.8  2413.9  1989.4  2437.7  2290.9
  2090.6  1406.3  1257.5  9143.8  5285.9  3556.4  8727.3  3352.1  2691.6
  2943.5  4720.7 14459.5  9897.5  7233.7  7392.4  7685.9  7473.7  6027.8
  4901.2  5648.9  4133.6  3423.5 15092.2 70889.2 71761.9 33540.5 25269.4
 13658.2  9197.3  7025.4  7812.9 12537.5  6567.3  5329.6  4115.7  3298.5
  3125.9  3425.5  2743.1  2358.3  2737.2  2653.9  2782.8  5381.1  4478.7
  3697.2  3607.9  2731.2  3280.7  2778.8  2955.4  2336.5  2257.2  1499.5
  1402.3  4651.2  7180.2  4387.4  3008.9  2249.3  1953.7  3723.0  7547.1
  5127.3  4446.9 10675.0  7733.5  8205.6 19933.9 16958.7  9594.0  7281.3
  6257.8  5658.8  4671.1  4764.3  4954.7  9421.5 20112.4  9296.5 11178.8
 32033.0 14804.6 24799.3 11256.2  6884.6  4264.5  3996.7  4881.3  3965.0
 30.   65.   93.   16.    5.7    0.
 46.   74.   93.   10.7   2.7    0.
 .95   .05   .00   .07   .80   .13   .00   .10   .90
```

```
.61  .38   .01
   2
  36
650.      92.5      0.
652.      157.5     250.
654.      262.5     630.
656.      392.5     1300.
658.      600.      2200.
660.      875.      3700.
662.      1025.0    5700.
664.      1075.0    7800.
666.      1300.     10000.
668.      1750.     13000.
670.      2125.     17000.
672.      2450.0    21500.
674.      2825.     27000.
676.      3500.     33000.
678.      4450.0    41000.
680.      4750.     50800.
682.      5550.     60000.
684.      7000.     73000.
686.      7750.     88000.
688.      8175.     104000.
690.      9000.     120700.
692.      10425.    140000.
694.      12250.    162400.
696.      13650.    189000.
698.      14375.    217000.
700.      15500.    246500.
702.      17375.    279000.
704.      19525.    316000.
706.      21000.    357100.
708.      21725.    400000.
710.      23000.    444000.
712.      24650.    492000.
714.      25825.    542600.
716.      27400.    595300.
718.      29175.    652200.
720.      30625.    712000.
   52
.98       .98       .98       .97       .92       .86       .80       .76
.68       .6        .54       .52       .5        .5        .45       .4
.41       .42       .42       .43       .43       .44       .45       .45
.46       .46       .46       .48       .48       .49       .50       .54
.58       .61       .62       .68       .77       .80       .82       .84
.86       .90       .92       .92       .93       .94       .97       .97
.97       .97       .975      .98
    1
     0.00      0.02      0.04      0.06      0.08      0.10      0.12      0.14
     0.16      0.18      0.20      0.22      0.24      0.26      0.28      0.30
     0.32      0.34      0.36      0.38      0.40      0.42      0.44      0.46
     0.48      0.50      0.52      0.54      0.56      0.58      0.60      0.62
     0.64      0.66      0.68      0.70      0.72      0.74      0.76      0.78
     0.80      0.82      0.84      0.86      0.88      0.90      0.92      0.94
     0.96      0.98      1.00
  -5.56    -1.5776   -.9505    -.7998    -.6737    -.6139    -.5654    -.5105
-.4771    -.4397    -.4067    -.379     -.3503    -.3311    -.3144    -.2998
-.2863    -.2716    -.2584    -.2463    -.2354    -.2235    -.2107    -.1907
-.1715    -.1534    -.1388    -.1199    -.1045    -0.0901   -.0751    -.0641
-.0546    -.0436    -.0338    -.0225    -.0049     .0151    .0543     .0952
.1414     .2119     .2968     .3524     .4559     .6156     .8509     1.2802


1.8758    2.9926    10.3618
   0.62828   0.62820   0.79689   0.92015   0.80472   0.60640   0.57973   0.67773
   0.68174   0.60932   0.67097   0.85808   0.90786   0.73221   0.57295   0.61025
   0.69600   0.65581   0.60762   0.73047   0.90217   0.86700   0.66221   0.56489
   0.64640   0.69704   0.62828   0.62820   0.79689   0.92015   0.80473   0.60640
   0.57973   0.67773   0.68174   0.60932   0.67097   0.85808   0.90786   0.73221
   0.57295   0.61025   0.69600   0.65581   0.60762   0.73047   0.90217   0.86700
   0.66221   0.56489   0.64639   0.69704
```

15847.360	14167.780	12659.110	11343.320	10239.570	9363.949	8729.355	8344.828
8216.055	8345.051	8729.797	9364.727	10240.470	11344.430	12660.450	14169.340
15849.030	17675.110	19620.810	21657.940	23756.720	25886.600	28016.370	30115.150
32152.160	34097.870	35923.830	37603.410	39112.080	40427.870	41531.610	42407.250
43041.950	43426.370	43555.140	43426.150	43041.400	42406.470	41530.730	40426.760
39110.750	37601.850	35922.270	34096.200	32150.380	30113.260	28014.480	25884.590
23754.820	21656.040	19619.030	17673.330				
12246.5	8820.0	6372.0	5254.6	5689.6	7733.1	11259.5	15968.7
21416.0	27061.1	32330.4	36685.3	39687.0	41051.0	40682.8	38691.8
35379.3	31204.7	26730.9	22557.6	19250.8	17274.9	16938.8	18360.3
21453.5	25941.7	31392.4	37270.3	43002.7	48046.9	51952.6	54411.6
55287.8	54625.4	52633.9	49652.8	46100.8	42416.9	39000.7	36160.9
34077.6	32784.2	32170.0	32003.9	31975.2	31745.9	31006.0	29526.1
27198.2	24059.4	20295.3	16221.4				
-.035	1.14						
.0	.0	.0					
-2.1997	-1.374	-.9695	-.8730	-.7917	-.7480	-.6802	-.6346
-.601	-.5774	-.5633	-.5439	-.531	-.4972	-.4884	-.4753
-.4632	-.4468	-.4323	-.4229	-.4022	-.3867	-.38	-.3598
-.3436	-.3259	-.3073	-.2815	-.2573	-.2444	-.2259	-.2088
-.1894	-.1384	-.1074	-.0516	.0152	.089	.1707	.2806
.4014	.5693	.7223	.8629	1.0864	1.4725	1.9023	2.2453
2.5421	2.9939	3.5136					
6861.42	12581.02	4879.13	13248.3	9541.89	7205.96	4474.28	3705.46
8772.57	3375.68	5721.25	3913.66	1934.54	298.4	18854.5	563.96
20394.56	31341.38	17169.11	28996.35	7703.19	1361.6	32319.38	32189.33
38824.88	26423.16	36992.95	39196.98	39072.57	86219.69	19415.02	11357.75
19806.05	26358.75	27444.71	40415.3	45504.59	34406.33	47601.84	52199.24
47059.2	52670.71	28940.84	17296.51	33943.94	26572.07	15100.63	8675.58
8045.07	4457.65	4086.29	5751.3				
11574.59	21588.07	7537.9	33815.39	18855.98	12339.37	8443.59	6602.16
14879.14	5948.32	14535.32	7166.49	2862.86	267.58	13347.	667.7
28570.7	43423.32	23928.56	40944.51	10824.13	1876.32	32870.36	33172.5
36829.98	44088.49	78937.31	70545.88	56497.36	138382.8	17124.45	11091.65
20139.41	40950.71	44075.04	49497.81	65293.11	62691.49	41767.46	72836.63
103228.	123676.	45608.51	27234.27	30677.9	41376.76	14190.57	10383.76
10472.75	5889.53	8497.7	13248.98				
.859	.889	.718	.783	.688	.57	.472	.399
.315	.236	.157	.079	.067	.059	0.059	.067
.079	.079	.079	.138	.169	.236	.315	.433
.531	.609	.854	.981	1.059	1.151	1.351	1.262
1.355	1.478	1.502	1.45	1.657	1.63	1.786	1.7
1.637	1.628	1.662	1.569	1.473	1.508	1.363	1.386
1.244	1.187	1.082	1.124				
-2.3828	-1.5994	-1.3065	-1.1251	-.9786	-.8322	-.6958	-.6027
-.5244	-.4568	-.4117	-.3279	-.2849	-.2403	-.1990	-.1562
-.1221	-.0943	-.0778	-.0565	-.0404	-.0311	-.0266	-.0266
-.0143	-.0104	-.003	.0051	.0111	.0141	.025	.0322
.039	.0482	.0653	.0850	.102	.1377	.1765	.2303
.2791	.3454	.4243	.5406	.6846	.8510	.9924	1.1814
1.4974	1.7415	7.2624					
655.	660.	665.5	669.	671.	673.3	675.	676.5
677.8	679.	680.5	681.	682.	682.7	683.5	684.2
685.	685.9	686.3	687.1	687.5	688.1	688.7	689.2
689.7	690.2	690.9	691.2	691.8	692.2	692.6	693.1
693.6	694.	694.3	695.	695.4	695.8	696.	696.5
697.0	697.3	697.8	698.	698.4	698.8	699.1	699.3
699.8	700.	700.3	700.8	701.	701.3	701.6	701.9
702.2	702.4	702.7	703.0	703.2	703.5	703.8	704.
704.2	704.5	704.8	705.0	705.2	705.4	705.7	706.1
706.3	706.6	706.9	707.0	707.2	707.5	707.8	708.
708.2	708.4	708.6	708.9	709.2	709.35	709.5	709.8
710.	710.2	710.6	710.8	711.	711.1	711.3	711.5
711.7	711.9	712.1	712.3	712.5	712.7	712.9	713.
713.2	713.3	713.6	713.8	714.	714.1	714.3	714.5
714.7	714.9	715.0	715.1	715.3	715.6	715.8	716.
716.2	716.4	716.7	716.9	717.1	717.2	717.35	717.5
717.62	717.78	718.0	718.15	718.31	718.46	718.61	718.77
718.92	719.08	719.23	719.39	719.54	719.69	719.85	720.

```
                                    3471.      5554.      7636.      10552.     11107.
16661.     22215.     27769.     30455.     34711.     38182.     41453.     45124.
55540.     62479.     69422.     72892.     83306.     104132.    118017.    124959.
138843.    159669.    173554.    190909.    208264.    215207.    222149.    236033.
239504.    267273.    288099.    301983.    312397.    331223.    347107.    364463.
374876.    381818.    406116.    426942.    437355.    451240.    475537.    489421.
0.         40264.     68030.     87470.     98580.     113850.    124960.    134400.
143010.    149950.    155500.    161060.    166610.    170080.    173550.    176610.
180500.    184660.    187440.    189800.    191600.    194380.    197160.    199240.
201320.    203000.    205490.    206880.    208960.    211040.    213820.    216320.
217980.    219090.    222150.    223260.    224930.    225620.    227420.    229090.
230200.    231870.    232980.    233260.    234640.    235620.    236030.    237000.
238390.    239500.    240890.    242560.    242980.    244360.    245060.    246450.
247560.    248530.    248950.    249920.    251030.    251720.    282420.    253940.
254500.    255470.    256170.    256860.    257690.    258250.    258800.    260330.
261720.    262410.    263110.    263800.    264220.    264770.    266330.    267130.
267550.    268380.    269360.    270470.    270740.    271160.    272130.    273240.
273520.    273800.    274350.    275190.    276020.    276300.    276580.    276990.
277270.    277550.    279070.    279630.    281160.    281850.    282130.    281850.
282350.    282850.    283370.    283790.    284340.    285460.    286290.    287405.
287960.    288520.    288793.    289070.    289950.    289630.    289900.    290180.
290880.    291570.    292260.    292960.    293580.    293790.    294210.    294490.
294900.    295320.    295740.    296200.    296570.    296990.    297260.    297680.
298100.    298500.    298790.    298930.    299210.    299480.    299660.    299900.
720.
   11
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.

683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
683.       6113.      67900.
681.5      5606.      59200.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
678.48     4510.      43480.
673.81     2973.      26387.
671.09     2270.      19453.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
670.       2025.      17000.
673.81     2973.      26387.
676.6      3810.      33910.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
680.       5175.      50800.
681.5      5606.      59200.
/*
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RESERVOIR OPERATION PLAN(WEEKLY ELEVATIONS) :

683.00	683.00	683.00
683.00	683.00	683.00
683.00	683.00	683.00
683.00	683.00	683.00
681.50	680.00	680.00
680.00	680.00	680.00
678.48	673.81	671.09
670.00	670.00	670.00
670.00	670.00	670.00
670.00	670.00	670.00
670.00	670.00	670.00
670.00	670.00	670.00
670.00	673.81	676.60
680.00	680.00	680.00
680.00	680.00	680.00
680.00	680.00	680.00
680.00	680.00	680.00
681.50		

RESERVOIR INFLOW TIME SERIES NUMBER 1
(ACRE-FT.)

42307.	14069.	9630.	6791.	8759.	6240.	4990.	4437.	4134.	3824.
15737.	7414.	4661.	4185.	3174.	2797.	3888.	2955.	2688.	1993.
2043.	1884.	1964.	2460.	28661.	53395.	29137.	91140.	156535.	113613.
40622.	23683.	25904.	41871.	26043.	30645.	52979.	45064.	54545.	31200.
14360.	9592.	36924.	22869.	13591.	9489.	7083.	6292.	5294.	4725.
3505.	4026.								

SEDIMENT INFLOW TIME SERIES NUMBER 1
(TONS)

43189.	19367.	12791.	8763.	4355.	1560.	4749.	1170.	1189.	7110.
882.	2792.	972.	196.	10247.	1228.	6371.	3402.	6669.	88370.
2944.	4191.	3600.	15608.	23585.	93900.	25211.	49119.	83682.	133390.
31640.	9986.	11343.	40291.	4663.	386.	304372.	10853.	21852.	23148.
81112.	209895.	26513.	3296.	36043.	8678.	13672.	8500.	18825.	11498.
2838.	681.								

PAN EVAPORATION TIME SERIES NUMBER 1
(IN.)

0.975	0.904	0.622	0.812	0.094	0.581	0.803	0.409	0.351	0.221	0.158	0.630
0.712	0.061	0.062	0.088	0.069	0.096	0.083	0.226	0.205	0.467	0.432	0.438
0.518	0.440	0.797	0.807	1.115	1.098	1.407	0.616	2.108	1.140	1.008	1.318
0.276	1.316	2.026	2.063	1.807	1.438	1.690	1.605	1.220	0.961	1.378	1.605

WEEKLY STANDARD DEVIATIONS OF WATER INFLOW(A-FT) :

12246.500	8820.000	6372.000	5254.598	5689.598	7733.098	11259.500	15968.699
21416.000	27061.098	32330.398	36685.297	39687.000	41051.000	40682.797	38691.797
35379.297	31204.699	26730.898	22557.598	19250.797	17274.898	16938.797	18360.297
21453.500	25941.699	31392.398	37270.297	43002.699	48046.898	51952.598	54411.598
55287.797	54625.398	52633.898	49652.797	46100.797	42416.898	39000.699	36160.898
34077.598	32784.199	32170.000	32003.898	31975.199	31745.898	31006.000	29526.098
27198.199	24059.398	20295.297	16221.398				

IDS= 11

NTI= 52

INITIAL RESERVOIR CHARACTERISTICS :

ELEV.	AREA	VOLUME
650.00	92.50	0.0
652.00	157.50	250.00
654.00	262.50	630.00
656.00	392.50	1300.00
658.00	600.00	2200.00
660.00	875.00	3700.00
662.00	1025.00	5700.00
664.00	1075.00	7800.00
666.00	1300.00	10000.00
668.00	1750.00	13000.00
670.00	2125.00	17000.00
672.00	2450.00	21500.00
674.00	2825.00	27000.00
676.00	3500.00	33000.00
678.00	4450.00	41000.00
680.00	4750.00	50800.00
682.00	5550.00	60000.00
684.00	7000.00	73000.00
686.00	7750.00	88000.00
688.00	8175.00	104000.00
690.00	9000.00	120700.00
692.00	10425.00	140000.00
694.00	12250.00	162400.00
696.00	13650.00	189000.00
698.00	14375.00	217000.00
700.00	15500.00	246500.00
702.00	17375.00	279000.00
704.00	19525.00	316000.00
706.00	21000.00	357100.00
708.00	21725.00	400000.00
710.00	23000.00	444000.00
712.00	24650.00	492000.00
714.00	25825.00	542600.00
716.00	27400.00	595300.00
718.00	29175.00	652200.00
720.00	30625.00	712000.00

COMPUTER MODEL OUTPUT

************HISTORICAL WATER INFLOW DATA USED************

SEDIMENT CHARACTERISTICS :

ASNL :

30.000	65.000	93.000	16.000	5.700	0.0
46.000	74.000	93.000	10.700	2.700	0.0

ASSL :

32.402	66.105	89.466	15.293	5.642	0.719
47.922	74.526	90.602	10.151	2.837	0.341

GGAMA= 45.780 LBS./CFT

DELTA= 0.0000250 ACRE-FT.

BETA= 0.030

SEDIMENT INFLOW FRACTIONS :

CLAY= 0.610 SILT= 0.380 SAND= 0.010

WEEKLY MEANS OF WATER INFLOW(A-FT) :

15847.359	14167.777	12659.109	11343.316	10239.566	9363.945	8729.352	8344.824
8216.055	8345.051	8729.797	9364.727	10240.469	11344.430	12660.449	14169.340
15849.027	17675.109	19620.809	21657.938	23756.719	25886.598	28016.367	30115.148
32152.156	34097.867	35923.828	37603.406	39112.078	40427.867	41531.609	42407.250
43041.949	43426.367	43555.137	43426.148	43041.398	42406.469	41530.727	40426.758
39110.750	37601.848	35922.270	34096.199	32150.379	30113.258	28014.477	25884.590
23754.816	21656.039	19619.027	17673.328				

1.249	2.264	1.065	0.934

RESERVOIR INFLOW TIME SERIES NUMBER 2
(ACRE-FT.)

6488.	3374.	3162.	8953.	8442.	5615.	4844.	5167.	21001.	18446.
12873.	13745.	12545.	10389.	9431.	8876.	20945.	12813.	99372.	37488.
27769.	16879.	13904.	11822.	12159.	9759.	7716.	7398.	8350.	188430.
169428.	61944.	80727.	46810.	72833.	147689.	64740.	65891.	64264.	33382.
27610.	27094.	17950.	14033.	23048.	13226.	10899.	7359.	6294.	5601.
5720.	7666.								

SEDIMENT INFLOW TIME SERIES NUMBER 2
(TONS)

8041.	431.	5110.	6912.	47445.	6338.	478.	42.	19399.	17176.
1111.	25765.	6054.	1364.	71226.	500.	31486.	86788.	96631.	114005.
6524.	531.	103599.	14030.	19301.	25309.	23399.	10285.	49091.	227202.
63011.	15123.	18991.	2319.	166326.	51213.	56062.	27122.	178402.	7973.
142973.	73906.	2137.	1397.	48049.	25727.	14720.	42960.	2863.	2753.
3912.	3717.								

PAN EVAPORATION TIME SERIES NUMBER 2
(IN.)

0.790	0.956	0.725	0.977	1.007	0.369	0.530	0.349	0.402	0.263	0.032	0.209
0.057	0.128	0.072	0.157	0.008	0.582	0.062	0.098	0.164	0.232	0.100	0.204
0.546	0.869	0.854	0.991	1.062	1.085	1.325	1.384	1.237	1.512	1.451	1.514
0.779	1.662	2.256	1.702	1.624	1.632	1.575	1.476	1.470	1.506	1.417	1.303
1.246	1.057	0.912	0.817								

RESERVOIR INFLOW TIME SERIES NUMBER 3
(ACRE-FT.)

4901.	3453.	4836.	16681.	8604.	6373.	5439.	5262.	14632.	8737.
7805.	6629.	5256.	4919.	4443.	3312.	3669.	3590.	3422.	3600.
2321.	1795.	2053.	16463.	69421.	46393.	103993.	95643.	66426.	64998.
71762.	36238.	36099.	35127.	23127.	17514.	15174.	13388.	11609.	31418.
21104.	13646.	9233.	9874.	7960.	11504.	15140.	25825.	19805.	9467.
6421.	4536.								

SEDIMENT INFLOW TIME SERIES NUMBER 3
(TONS)

9669.	52118.	5649.	28639.	426.	102.	12475.	3219.	30183.	1329.
11366.	4984.	584.	227.	15528.	453.	17942.	3529.	6284.	1213.
3652.	626.	59595.	123300.	63406.	23951.	88586.	81643.	122398.	536721.
17962.	11480.	2309.	3843.	2135.	117231.	31842.	2787.	37430.	80734.
17366.	70716.	114318.	34311.	58153.	20672.	8468.	13328.	3680.	867.
121.	3006.								

PAN EVAPORATION TIME SERIES NUMBER 3
(IN.)

0.413	0.892	0.720	0.599	0.676	0.587	0.452	0.363	0.300	0.396	0.146	0.191

0.251	0.022	0.048	0.159	0.142	0.094	0.044	0.171	0.360	0.335	0.095	0.423
0.632	0.616	0.981	0.987	1.462	1.148	1.374	1.256	1.027	0.879	1.019	1.305
0.623	1.606	1.777	1.936	1.639	1.479	1.688	1.738	1.166	1.498	1.368	1.407
1.075	1.147	1.470	1.111								

RESERVOIR INFLOW TIME SERIES NUMBER 4
(ACRE-FT.)

4106.	20013.	9999.	7876.	32569.	21521.	23008.	16582.	31478.	34651.
40939.	43279.	31240.	24496.	18089.	19438.	16463.	15471.	12516.	10988.
9084.	9759.	14678.	18050.	14261.	12040.	11782.	23008.	102843.	184661.
145587.	98459.	64403.	38420.	30109.	38737.	39927.	24377.	59246.	51312.
37329.	20450.	15332.	15620.	31716.	123967.	97864.	40185.	24119.	15719.
12803.	11086.								

SEDIMENT INFLOW TIME SERIES NUMBER 4
(TONS)

384.	12084.	22182.	90068.	47123.	8267.	4094.	3770.	22545.	3824.
10543.	9665.	2503.	361.	19400.	260.	21024.	88798.	59096.	18333.
48855.	276.	20050.	34893.	25398.	546.	6984.	52003.	44850.	200942.
29079.	12559.	32467.	435.	45245.	311.	86943.	72106.	63768.	29076.
72105.	401211.	9065.	7062.	64480.	68306.	28722.	7514.	3242.	3450.
37002.	47986.								

PAN EVAPORATION TIME SERIES NUMBER 4
(IN.)

3.051	0.895	0.809	0.869	0.134	0.209	0.155	0.020	0.321	0.226	0.152	0.189
0.107	0.077	0.073	0.481	0.096	0.304	0.642	0.161	0.169	0.190	0.327	0.563
0.335	0.585	0.899	0.984	1.057	1.261	1.988	0.965	1.354	1.442	2.081	1.400
0.502	1.770	1.784	1.736	1.395	0.986	1.493	1.571	1.864	1.810	1.396	1.159
1.071	1.177	3.822	1.101								

RESERVOIR INFLOW TIME SERIES NUMBER 5
(ACRE-FT.)

21180.	27035.	14291.	9904.	11526.	14608.	4425.	2466.	10310.	12083.
9541.	8430.	7716.	7240.	6470.	5943.	3455.	1494.	1511.	3788.
4284.	4066.	4503.	3749.	3372.	2579.	4304.	6407.	7676.	6208.
26936.	53355.	566479.	151101.	26539.	15679.	11564.	12065.	23096.	39650.
33124.	30605.	16939.	14390.	17153.	16711.	10155.	9318.	13785.	22453.
31557.	17976.								

SEDIMENT INFLOW TIME SERIES NUMBER 5
(TONS)

5954.	25234.	5545.	65393.	24830.	6807.	6161.	4902.	1008.	8320.
39912.	9879.	1868.	295.	15397.	305.	60552.	23083.	47022.	35725.
377.	7169.	16155.	6344.	13990.	58501.	22025.	11095.	145423.	37917.
12187.	10308.	117628.	42854.	7039.	39479.	50470.	7331.	34857.	28592.
58565.	10640.	18268.	15139.	25335.	74997.	10513.	17214.	5037.	1871.
8750.	2729.								

PAN EVAPORATION TIME SERIES NUMBER 5

(IN.)

0.881	0.859	0.465	1.038	0.895	0.812	0.460	0.413	0.351	0.231	0.124	0.103
0.001	0.502	0.140	0.222	0.069	0.124	0.677	0.383	0.178	0.337	0.408	0.750
0.525	0.623	0.913	0.962	1.126	1.065	1.261	1.284	1.401	1.474	0.766	1.595
0.711	1.639	1.885	1.727	1.590	2.196	1.483	1.561	1.507	1.496	1.365	1.450
0.955	1.197	1.015	1.129								

RESERVOIR INFLOW TIME SERIES NUMBER 6
(ACRE-FT.)

12377.	10691.	6311.	5431.	5611.	4707.	4046.	3808.	3314.	2930.
2672.	3025.	2779.	2646.	2596.	2602.	3519.	2894.	2339.	1726.
1089.	1069.	1107.	1343.	1553.	2466.	2479.	2727.	2856.	2783.
2825.	3146.	4477.	3824.	3215.	13024.	10919.	10858.	13488.	18922.
23445.	19517.	14386.	10451.	7154.	13623.	43220.	19989.	14515.	18982.
14027.	7103.								

SEDIMENT INFLOW TIME SERIES NUMBER 6
(TONS)

19949.	12218.	3539.	1948.	2327.	18408.	213.	2911.	1721.	13287.
5096.	5417.	3066.	200.	18881.	420.	13767.	196616.	109573.	13339.
10830.	293.	5521.	6671.	63855.	43486.	388932.	54360.	19776.	23464.
29873.	20078.	12984.	146801.	53936.	22535.	42299.	59735.	21758.	12216.
514.	109535.	5818.	9038.	10472.	104000.	19309.	5618.	4692.	1297.
933.	11068.								

PAN EVAPORATION TIME SERIES NUMBER 6
(IN.)

0.366	0.879	0.683	0.773	0.646	0.568	0.467	0.512	0.534	0.304	0.203	0.094
1.101	0.046	0.197	0.503	0.210	0.144	0.058	0.018	0.159	0.284	0.320	0.400
0.417	0.604	2.471	0.940	1.229	0.949	1.788	1.401	1.558	2.050	1.530	0.868
0.812	1.275	1.331	1.780	1.409	1.700	1.627	1.404	1.698	1.031	1.291	1.523
1.247	1.168	1.105	0.939								

RESERVOIR INFLOW TIME SERIES NUMBER 7
(ACRE-FT.)

9933.	6766.	4261.	3902.	6573.	8218.	11042.	13916.	8638.	5794.
4770.	4257.	3906.	3909.	3531.	3477.	2489.	2469.	2390.	3451.
2321.	2103.	10076.	4582.	3055.	26281.	3253.	43339.	25983.	26579.
45025.	55934.	46017.	39669.	73983.	219173.	204099.	108297.	83088.	37626.
23683.	16542.	23445.	57699.	61944.	31418.	19081.	18637.	22552.	48159.
21501.	11701.								

SEDIMENT INFLOW TIME SERIES NUMBER 7
(TONS)

50242.	3597.	34026.	21385.	78968.	1005.	36081.	2483.	4955.	19308.
34024.	2773.	1165.	249.	17790.	1619.	3325.	203338.	73372.	10494.
10268.	2982.	31589.	19472.	28176.	1406.	136130.	32370.	40941.	64398.
62031.	8441.	20645.	106330.	37905.	168354.	122313.	88363.	66704.	42321.
5960.	267716.	10867.	27054.	39987.	19416.	10285.	6611.	16012.	9720.
14213.	6069.								

PAN EVAPORATION TIME SERIES NUMBER 7
(IN.)

0.646	1.059	0.706	0.664	0.671	0.560	0.468	0.215	0.295	0.225	0.116	0.062
0.032	0.060	0.029	0.036	0.395	0.145	0.303	0.133	0.096	0.211	0.074	0.328
0.673	0.613	0.796	0.939	1.190	1.354	1.443	1.518	1.390	1.504	1.489	0.902
0.695	1.644	2.019	1.712	1.254	1.650	1.290	0.844	1.486	1.517	1.329	1.275
1.286	0.814	1.194	1.235								

RESERVOIR INFLOW TIME SERIES NUMBER 8
(ACRE-FT.)

7587.	6042.	4586.	4899.	15277.	19537.	40344.	72139.	107960.	102347.
67934.	33699.	37726.	26995.	21937.	28721.	23008.	20112.	19180.	23445.
27927.	28860.	32549.	28463.	21223.	13250.	8826.	33203.	37488.	18982.
15094.	16701.	16463.	39848.	42545.	36833.	30565.	27332.	24436.	22750.
24952.	60555.	58909.	52721.	33917.	112483.	100006.	38380.	31636.	20271.
15741.	16685.								

SEDIMENT INFLOW TIME SERIES NUMBER 8
(TONS)

15568.	10439.	3737.	5323.	7411.	5964.	11396.	17213.	20276.	12179.
20187.	2741.	3229.	521.	21734.	643.	9881.	27268.	18276.	33510.
35351.	2953.	28163.	66566.	71141.	32024.	49623.	12516.	279985.	507963.
5562.	10539.	9838.	169.	25063.	33809.	29728.	53159.	136896.	15408.
3534.	156504.	27161.	113555.	47197.	103527.	27084.	6405.	61648.	11129.
21251.	25383.								

PAN EVAPORATION TIME SERIES NUMBER 8
(IN.)

0.854	0.723	0.578	0.802	0.316	0.534	1.038	0.212	0.287	0.236	0.072	0.126
0.072	0.077	0.039	0.084	0.429	0.075	0.110	0.121	0.223	0.199	0.182	0.224
0.566	0.207	0.708	0.377	1.543	0.993	1.383	1.164	1.344	1.537	1.510	0.559
0.790	1.725	1.522	1.557	1.526	1.647	1.488	1.919	1.425	1.496	1.154	1.299
1.239	1.618	1.374	1.063								

RESERVOIR INFLOW TIME SERIES NUMBER 9
(ACRE-FT.)

12799.	8640.	6944.	8604.	6585.	4401.	3691.	3203.	2731.	2648.
2596.	3310.	2464.	2180.	2414.	1989.	2438.	2291.	2091.	1406.
1258.	9144.	5286.	3556.	8727.	3352.	2692.	2944.	4721.	14460.
9898.	7234.	7392.	7686.	7474.	6028.	4901.	5649.	4134.	3424.
15092.	70889.	71762.	33541.	25269.	13658.	9197.	7025.	7813.	12538.
6567.	5330.								

SEDIMENT INFLOW TIME SERIES NUMBER 9
(TONS)

1569.	18040.	784.	115722.	85578.	22552.	735.	13773.	6708.	755.
39302.	34471.	2133.	75.	66003.	304.	7844.	23915.	6781.	6183.
7058.	228.	25112.	9097.	11531.	162432.	61099.	251119.	71730.	329316.

37977.	6891.	11130.	19902.	207462.	79268.	20054.	1323.	18503.	7307.
130851.	23440.	19164.	45996.	75580.	19755.	16968.	5900.	5464.	1786.
27625.	874.								

PAN EVAPORATION TIME SERIES NUMBER 9
(IN.)

0.779	0.659	0.725	0.792	0.538	0.560	0.461	0.431	0.241	0.179	0.169	0.297
0.053	0.075	0.007	0.111	0.028	0.109	0.070	0.159	0.182	0.248	0.280	0.461
0.523	1.051	0.633	0.812	0.473	1.216	1.369	1.243	1.328	1.483	2.287	1.418
0.791	1.916	1.977	1.305	1.874	1.659	1.648	0.941	0.933	1.419	1.728	1.372
1.022	0.935	1.454	1.202								

RESERVOIR INFLOW TIME SERIES NUMBER 10
(ACRE-FT.)

4116.	3299.	3126.	3426.	2743.	2358.	2737.	2654.	2783.	5381.
4479.	3697.	3608.	2731.	3281.	2779.	2955.	2337.	2257.	1500.
1402.	4651.	7180.	4387.	3009.	2249.	1954.	3723.	7547.	5127.
4447.	10675.	7734.	8206.	19934.	16959.	9594.	7281.	6258.	5659.
4671.	4764.	4955.	9422.	20112.	9297.	11179.	32033.	14805.	24799.
11256.	6885.								

SEDIMENT INFLOW TIME SERIES NUMBER 10
(TONS)

927.	2510.	133.	17318.	4853.	55771.	5300.	3891.	7978.	972.
8310.	65.	11672.	600.	20553.	340.	17979.	25930.	55845.	23790.
1346.	2007.	26444.	2681.	11186.	209029.	35645.	116077.	8351.	696567.
44041.	47937.	88582.	173922.	7897.	81784.	143914.	55301.	7706.	25465.
38797.	91875.	200180.	5260.	30122.	158444.	5626.	9234.	43868.	4385.
36891.	14874.								

PAN EVAPORATION TIME SERIES NUMBER 10
(IN.)

1.003	0.165	0.723	0.200	0.722	0.541	0.923	0.404	0.429	0.490	0.131	0.170
0.394	0.057	0.087	0.954	0.074	0.088	0.095	0.584	0.797	0.051	0.942	0.488
0.560	0.330	0.453	1.415	0.806	1.736	1.433	1.252	1.351	1.477	3.134	1.459
0.672	1.929	2.448	0.931	1.627	1.837	1.818	1.673	1.055	1.517	0.754	1.415
1.294	1.639	1.237	3.409								

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HH,AVPOOL ARE IN FT.
OUTPL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 27.4 AVPOOL = 677.4 OUTPL= 0.0 ACQS= 1540679.0
RESVOL= 2215103.0 EVT= 1442793.0

ELEVATION-VOLUME-AREA RELATION AFTER 1 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)	VOLUME (AFT)	AREA (ACRES)
650.		0.0	0.0
	74.85		
650.44(ZERO ELEVATION)		0.0	92.76
652.		175.15	131.19
	68.46		
654.		486.69	223.04
	89.37		
656.		1067.32	344.03
	104.50		
658.		1862.82	544.94
	115.74		
660.		3247.08	815.10
	123.86		
662.		5123.22	961.73
	129.21		
664.		7094.01	1009.73
	131.87		
666.		9162.14	1234.09
	131.76		
668.		12030.39	1684.92
	128.57		
670.		15901.81	2062.45
	121.65		
672.		20280.17	2442.20
	109.57		
674.		25670.60	2825.53
	88.32		
676.		31582.28	3468.59
	37.32		
678.		39544.96	4440.67
	0.0		
680.		49344.96	4750.00
	0.0		
682.		58544.96	5549.99
	0.0		
684.		71544.94	6999.99
	0.0		
686.		86544.94	7750.00
	0.0		
688.		102544.94	8175.00
	0.0		
690.		119244.94	9000.00
	0.0		
692.		138544.94	10425.00
	0.0		
694.		160944.94	12250.00
	0.0		
696.		187544.94	13650.00
	0.0		
698.		215544.94	14375.00
	0.0		
700.		245044.94	15500.00

702.	0.0	277544.94	17375.00
704.	0.0	314544.94	19525.00
706.	0.0	355644.94	21000.00
708.	0.0	398544.94	21725.00
710.	0.0	442544.94	23000.00
712.	0.0	490544.94	24650.00
714.	0.0	541144.94	25825.00
716.	0.0	593844.94	27400.00
718.	0.0	650744.94	29175.00
720.	0.0	710544.94	30625.00

****

HH,AVPOOL ARE IN FT.
OUTFL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 27.4 AVPOOL = 677.8 OUTFL= 0.0 ACQS= 1977213.0
RESVOL= 2196092.0 EVT= 1821806.0

ELEVATION-VOLUME-AREA RELATION AFTER 2 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)		VOLUME (AFT)	AREA (ACRES)
650.			0.0	0.0
	69.10	79.57		
650.95 (ZERO ELEVATION)			0.0	89.85
652.			101.32	104.05
	63.21	79.75		
654.			338.36	178.96
	82.51	108.68		
656.			817.17	288.27
	96.48	129.23		
658.			1491.46	480.74
	106.86	144.49		
660.			2740.11	744.67

662.	114.36	155.63	4470.13	886.89
664.	119.29	163.16	6287.68	932.13
666.	121.75	167.27	8198.66	1154.02
668.	127.03	167.89	10903.74	1603.43
670.	126.67	164.70	14612.37	1982.95
672.	119.85	156.98	18835.55	2368.01
674.	107.94	143.19	24084.41	2760.62
676.	87.01	119.38	29878.02	3426.10
678.	37.07	52.12	37788.83	4427.70
680.	0.0	0.0	47588.83	4750.00
682.	0.0	0.0	56788.83	5550.00
684.	0.0	0.0	69788.81	7000.00
686.	0.0	0.0	84788.81	7750.00
688.	0.0	0.0	100788.81	8175.00
690.	0.0	0.0	117488.81	9000.00
692.	0.0	0.0	136788.81	10425.00
694.	0.0	0.0	159188.81	12250.00
696.	0.0	0.0	185788.81	13650.00
698.	0.0	0.0	213788.81	14375.00
700.	0.0	0.0	243288.81	15500.00
702.	0.0	0.0	275788.81	17375.00
704.	0.0	0.0	312788.81	19525.00
706.	0.0	0.0	353888.81	21000.00
708.	0.0	0.0	396788.81	21725.00
710.	0.0	0.0	440788.81	23000.00
712.	0.0	0.0	488788.81	24650.00
714.	0.0	0.0	539388.81	25825.00
716.	0.0	0.0	592088.81	27400.00
718.	0.0	0.0	648988.81	29175.00
720.	0.0	0.0	708788.81	30625.00

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HH,AVPOOL ARE IN FT.
OUTFL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 26.2 AVPOOL = 677.1 OUTFL= 0.0 ACQS= 1962547.0
RESVOL= 2011839.0 EVT= 1868126.0

ELEVATION-VOLUME-AREA RELATION AFTER 3 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)			VOLUME (AFT)	AREA (ACRES)
650.				0.0	0.0
	63.01	73.47	66.80		
651.43 (ZERO ELEVATION)				0.0	80.30
652.				46.72	82.57
	57.64	73.63	75.71		
654.				219.75	139.21
	75.24	100.34	110.62		
656.				603.55	235.53
	87.97	119.31	134.41		
658.				1161.85	418.91
	97.44	133.40	151.80		
660.				2279.20	676.27
	104.28	143.69	164.33		
662.				3866.91	813.90
	108.78	150.64	172.67		
664.				5534.82	856.35
	111.02	154.43	177.05		
666.				7292.32	1074.57
	121.82	160.03	177.36		
668.				9833.11	1520.25
	124.35	162.26	173.18		
670.				13373.32	1901.01
	116.69	155.93	163.53		
672.				17437.17	2292.58
	105.10	142.23	146.21		
674.				22543.63	2697.18
	84.72	118.59	114.43		
676.				28225.90	3386.73
	36.63	51.91	46.81		
678.				36090.54	4416.16
	0.0	0.0	0.0		
680.				45890.54	4750.00
	0.0	0.0	0.0		

682.	0.0	0.0	0.0	55090.54	5549.99
684.	0.0	0.0	0.0	68090.50	6999.99
686.	0.0	0.0	0.0	83090.50	7750.00
688.	0.0	0.0	0.0	99090.50	8175.00
690.	0.0	0.0	0.0	115790.50	9000.00
692.	0.0	0.0	0.0	135090.50	10425.00
694.	0.0	0.0	0.0	157490.50	12250.00
696.	0.0	0.0	0.0	184090.50	13650.00
698.	0.0	0.0	0.0	212090.50	14375.00
700.	0.0	0.0	0.0	241590.50	15500.00
702.	0.0	0.0	0.0	274090.50	17375.00
704.	0.0	0.0	0.0	311090.50	19525.00
706.	0.0	0.0	0.0	352190.50	21000.00
708.	0.0	0.0	0.0	395090.50	21725.00
710.	0.0	0.0	0.0	439090.50	23000.00
712.	0.0	0.0	0.0	487090.50	24650.00
714.	0.0	0.0	0.0	537690.50	25825.00
716.	0.0	0.0	0.0	590390.50	27400.00
718.	0.0	0.0	0.0	647290.50	29175.00
720.				707090.50	30625.00

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HH,AVPOOL ARE IN FT.
OUTFL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 26.2 AVPOOL = 677.7 OUTFL= 3082.3 ACQS= 2001247.0
RESVOL= 2005965.0 EVT= 1809772.0

ELEVATION-VOLUME-AREA RELATION AFTER 4 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)				VOLUME (AFT)	AREA (ACRES)
650.					0.0	0.0
	62.71	70.88	65.72	50.70		
652.					0.0	0.0
	51.32	63.26	65.85	64.76		
652.00(ZERO ELEVATION)					0.0	25.24
654.					134.81	109.73
	71.11	91.49	102.13	101.20		
656.					438.87	190.41
	83.15	108.80	124.10	126.38		
658.					896.45	364.75
	92.09	121.64	140.15	144.68		
660.					1897.88	615.54
	98.55	131.02	151.72	157.98		
662.					3358.60	748.51
	102.81	137.36	159.42	167.10		
664.					4891.91	787.95
	104.92	140.82	163.46	172.32		
666.					6510.39	1001.35
	118.74	151.51	169.19	173.64		
668.					8897.31	1440.86
	122.87	159.29	170.62	170.72		
670.					12273.82	1820.86
	113.20	154.63	162.44	162.79		
672.					16180.76	2217.65
	101.96	141.05	145.23	148.11		
674.					21144.41	2632.04
	82.18	117.60	113.67	122.04		
676.					26708.92	3344.36
	36.14	51.66	46.62	52.64		
678.					34521.86	4403.23
	0.0	0.0	0.0	0.0		
680.					44321.86	4750.00
	0.0	0.0	0.0	0.0		
682.					53521.86	5549.99
	0.0	0.0	0.0	0.0		
684.					66521.81	6999.99
	0.0	0.0	0.0	0.0		
686.					81521.81	7750.00
	0.0	0.0	0.0	0.0		
688.					97521.81	8175.00
	0.0	0.0	0.0	0.0		
690.					114221.81	9000.00
	0.0	0.0	0.0	0.0		
692.					133521.81	10425.00
	0.0	0.0	0.0	0.0		
694.					155921.81	12250.00
	0.0	0.0	0.0	0.0		
696.					182521.81	13650.00
	0.0	0.0	0.0	0.0		
698.					210521.81	14375.00
	0.0	0.0	0.0	0.0		
700.					240021.81	15500.00
	0.0	0.0	0.0	0.0		
702.					272521.81	17375.00

	0.0	0.0	0.0	0.0		
704.					309521.81	19525.00
	0.0	0.0	0.0	0.0		
706.					350621.81	21000.00
	0.0	0.0	0.0	0.0		
708.					393521.81	21725.00
	0.0	0.0	0.0	0.0		
710.					437521.81	23000.00
	0.0	0.0	0.0	0.0		
712.					485521.81	24650.00
	0.0	0.0	0.0	0.0		
714.					536121.81	25825.00
	0.0	0.0	0.0	0.0		
716.					588821.81	27400.00
	0.0	0.0	0.0	0.0		
718.					645721.81	29175.00
	0.0	0.0	0.0	0.0		
720.					705521.81	30625.00

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HH,AVPOOL ARE IN FT.
OUTFL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 26.8 AVPOOL = 678.9 OUTFL= 9974.0 ACQS= 1306990.0
RESVOL= 2310099.0 EVT= 1186825.0

ELEVATION-VOLUME-AREA RELATION AFTER 5 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)					VOLUME (AFT)	AREA (ACRES)
650.						0.0	0.0
	62.99	70.33	63.28	50.15	3.24		
652.						0.0	0.0
	46.54	56.44	56.69	56.45	54.75		
652.63(ZERO ELEVATION)						0.0	57.28
654.						109.13	102.47
	68.31	86.47	93.13	93.44	57.55		
656.						380.22	170.87
	79.87	102.82	113.16	116.69	75.08		
658.						792.60	339.97
	88.47	114.97	127.80	133.58	87.70		
660.						1740.09	586.94
	94.67	123.83	138.35	145.86	97.02		
662.						3140.36	717.10

664.	98.76	129.82	145.37	154.27	103.66	4608.48	754.55
666.	100.79	133.09	149.05	159.10	107.90	6158.55	963.31
668.	116.61	146.56	160.33	163.51	109.81	8461.73	1394.76
670.	121.78	157.39	167.49	168.20	109.29	11737.57	1770.95
672.	109.44	153.79	161.09	161.70	106.02	15545.54	2169.66
674.	98.57	140.28	144.02	147.12	99.31	20416.23	2588.17
676.	79.46	116.96	112.72	121.23	87.63	25898.23	3307.60
678.	35.61	51.49	46.38	52.40	65.74	33646.61	4383.79
680.	0.0	0.0	0.0	0.0	13.20	43433.41	4743.60
682.	0.0	0.0	0.0	0.0	0.0	52621.02	5546.89
684.	0.0	0.0	0.0	0.0	0.0	65621.00	6999.99
686.	0.0	0.0	0.0	0.0	0.0	80621.00	7750.00
688.	0.0	0.0	0.0	0.0	0.0	96621.00	8175.00
690.	0.0	0.0	0.0	0.0	0.0	113321.00	9000.00
692.	0.0	0.0	0.0	0.0	0.0	132621.00	10425.00
694.	0.0	0.0	0.0	0.0	0.0	155021.00	12250.00
696.	0.0	0.0	0.0	0.0	0.0	181621.00	13650.00
698.	0.0	0.0	0.0	0.0	0.0	209621.00	14375.00
700.	0.0	0.0	0.0	0.0	0.0	239121.00	15500.00
702.	0.0	0.0	0.0	0.0	0.0	271621.00	17375.00
704.	0.0	0.0	0.0	0.0	0.0	308621.00	19525.00
706.	0.0	0.0	0.0	0.0	0.0	349721.00	21000.00
708.	0.0	0.0	0.0	0.0	0.0	392621.00	21725.00
710.	0.0	0.0	0.0	0.0	0.0	436621.00	23000.00
712.	0.0	0.0	0.0	0.0	0.0	484621.00	24650.00
714.	0.0	0.0	0.0	0.0	0.0	535221.00	25825.00
716.	0.0	0.0	0.0	0.0	0.0	587921.00	27400.00
718.	0.0	0.0	0.0	0.0	0.0	644821.00	29175.00
720.	0.0	0.0	0.0	0.0	0.0	704621.00	30625.00

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HH,AVPOOL  ARE IN FT.
OUTFL,RESVOL  ARE IN ACRE-FT.
ACQS, EVT  ARE IN  TONS

HH =    24.5      AVPOOL =      677.1   OUTFL=       0.0    ACQS=      1764579.0
RESVOL=      1828201.0    EVT=        1744532.0
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ELEVATION-VOLUME-AREA RELATION AFTER 6 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)						VOLUME (AFT)	AREA (ACRES)
650.							0.0	0.0
	62.86	69.70	61.93	47.76	7.75	0.0		
652.							0.0	0.0
	43.34	52.08	51.46	49.44	48.55	66.98		
653.10(ZERO ELEVATION)							0.0	67.07
654.							68.16	83.78
	66.23	83.07	88.02	85.20	53.14	85.35		
656.							277.15	132.87
	77.44	98.78	106.95	106.40	69.32	118.62		
658.							599.65	290.31
	85.77	110.44	120.78	121.80	80.97	141.48		
660.							1438.40	529.21
	91.79	118.95	130.76	133.00	89.57	157.82		
662.							2716.51	653.71
	95.75	124.71	137.39	140.67	95.70	169.03		
664.							4053.25	687.50
	97.72	127.85	140.87	145.07	99.62	175.62		
666.							5466.50	892.06
	114.98	143.16	155.18	152.66	101.39	177.65		
668.							7621.49	1316.71
	120.93	156.00	165.50	165.11	105.86	174.76		
670.							10733.32	1690.32
	105.50	153.17	160.21	160.36	105.31	166.01		
672.							14382.77	2094.44
	95.02	139.71	143.24	145.90	98.65	149.16		
674.							19111.09	2524.64
	76.59	116.48	112.11	120.22	87.04	117.30		
676.							24481.34	3268.02
	35.05	51.36	46.23	52.10	65.30	48.13		
678.							32183.16	4373.77
	0.0	0.0	0.0	0.0	6.77	0.0		
680.							41976.41	4746.72
	0.0	0.0	0.0	0.0	0.0	0.0		
682.							51170.06	5548.41
	0.0	0.0	0.0	0.0	0.0	0.0		

684.	0.0	0.0	0.0	0.0	0.0	0.0	64170.06	6999.98
686.	0.0	0.0	0.0	0.0	0.0	0.0	79170.00	7749.98
688.	0.0	0.0	0.0	0.0	0.0	0.0	95170.00	8175.00
690.	0.0	0.0	0.0	0.0	0.0	0.0	111870.00	9000.00
692.	0.0	0.0	0.0	0.0	0.0	0.0	131170.00	10425.00
694.	0.0	0.0	0.0	0.0	0.0	0.0	153570.00	12250.00
696.	0.0	0.0	0.0	0.0	0.0	0.0	180170.00	13650.00
698.	0.0	0.0	0.0	0.0	0.0	0.0	208170.00	14375.00
700.	0.0	0.0	0.0	0.0	0.0	0.0	237670.00	15500.00
702.	0.0	0.0	0.0	0.0	0.0	0.0	270170.00	17375.00
704.	0.0	0.0	0.0	0.0	0.0	0.0	307170.00	19525.00
706.	0.0	0.0	0.0	0.0	0.0	0.0	348270.00	21000.00
708.	0.0	0.0	0.0	0.0	0.0	0.0	391170.00	21725.00
710.	0.0	0.0	0.0	0.0	0.0	0.0	435170.00	23000.00
712.	0.0	0.0	0.0	0.0	0.0	0.0	483170.00	24650.00
714.	0.0	0.0	0.0	0.0	0.0	0.0	533770.00	25825.00
716.	0.0	0.0	0.0	0.0	0.0	0.0	586470.00	27400.00
718.	0.0	0.0	0.0	0.0	0.0	0.0	643370.00	29175.00
720.							703170.00	30625.00

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HH,AVPOOL  ARE IN FT.
OUTPL,RESVOL  ARE IN ACRE-FT.
ACQS, EVT  ARE IN  TONS

HH =   24.8     AVPOOL =     677.9   OUTPL=  3706.1   ACQS=      2125236.0
RESVOL=     1888917.0   EVT=      1969559.0
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ELEVATION-VOLUME-AREA RELATION AFTER 7 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)							VOLUME (AFT)	AREA (ACRES)
650.								0.0	0.0
	62.42	68.91	60.79	46.38	11.48	0.02	0.0		
652.								0.0	0.0
	41.15	49.16	48.13	45.49	43.10	60.21	60.63		
653.52(ZERO ELEVATION)								0.0	65.02
654.								32.13	67.96
	64.59	80.54	84.55	80.53	48.45	78.80	84.43		
656.								180.23	93.54
	75.52	95.77	102.74	100.56	63.21	109.52	126.62		
658.								406.30	236.26
	83.65	107.07	116.03	115.12	73.83	130.62	154.69		
660.								1125.29	465.16
	89.52	115.33	125.61	125.70	81.67	145.71	174.82		
662.								2266.93	582.54
	93.38	120.91	131.98	132.95	87.27	156.06	188.94		
664.								3455.45	611.51
	95.30	123.95	135.33	137.11	90.84	162.14	197.82		
666.								4712.96	811.37
	113.69	140.60	151.63	146.43	92.45	165.58	201.66		
668.								6700.92	1227.76
	120.23	154.91	164.04	163.15	102.22	172.18	200.20		
670.								9623.99	1596.98
	101.43	152.67	159.56	159.48	104.43	164.91	192.65		
672.								13088.85	2005.83
	91.36	139.26	142.66	145.11	97.83	148.17	177.15		
674.								17647.32	2446.46
	73.64	116.11	111.66	119.56	86.32	116.51	148.85		
676.								22874.67	3216.41
	34.48	51.26	46.11	51.91	64.76	47.91	65.30		
678.								30512.95	4358.70
	0.0	0.0	0.0	0.0	3.46	0.0	0.0		
680.								40309.50	4748.32
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
682.								49506.25	5549.19
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
684.								62506.25	7000.00
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
686.								77506.25	7750.00

688.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93506.25	8175.00
690.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110206.25	9000.00
692.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	129506.25	10425.00
694.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	151906.25	12250.00
696.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	178506.25	13650.00
698.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	206506.25	14375.00
700.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	236006.25	15500.00
702.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	268506.25	17375.00
704.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	305506.25	19525.00
706.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	346606.25	21000.00
708.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	389506.25	21725.00
710.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	433506.25	23000.00
712.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	481506.25	24650.00
714.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	532106.25	25825.00
716.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	584806.25	27400.00
718.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	641706.25	29175.00
720.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	701506.25	30625.00

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HH,AVPOOL ARE IN FT.
OUTPL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 23.6 AVPOOL = 677.2 OUTPL= 8685.3 ACQS= 2258318.0
RESVOL= 1681191.0 EVT= 2067777.0

ELEVATION-VOLUME-AREA RELATION AFTER 8 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)								VOLUME (AFT)	AREA (ACRES)
650.	62.96	69.23	60.72	45.89	11.18	0.02	0.0	0.0	0.0	0.0
652.	41.10	49.20	48.31	45.59	42.72	57.57	59.16	36.35	0.0	0.0
654.	60.61	75.26	78.55	74.12	43.88	68.86	74.70	96.86	0.0	0.0
654.27(ZERO ELEVATION)									0.0	52.95
656.	73.95	93.40	99.61	96.60	59.74	99.87	116.90	133.76	97.16	59.37
658.	81.91	104.42	112.49	110.58	69.78	119.11	142.82	167.19	223.33	179.47
660.	87.66	112.47	121.78	120.75	77.19	132.87	161.40	190.71	815.03	396.71
662.	91.44	117.92	127.96	127.72	82.48	142.30	174.44	206.95	1810.19	505.99
664.	93.32	120.89	131.20	131.71	85.85	147.85	182.64	216.88	2838.99	529.61
666.	112.62	138.57	148.97	142.17	87.38	152.61	186.18	220.75	3928.64	725.11
668.	119.64	154.02	162.89	161.71	100.19	169.02	196.29	218.17	5739.41	1132.21
670.	97.30	152.26	159.05	158.84	103.86	163.53	191.37	207.99	8457.49	1495.97
672.	87.64	138.89	142.20	144.52	97.29	146.94	175.98	187.43	11723.28	1911.23
674.	70.64	115.80	111.30	119.08	85.85	115.55	147.86	147.78	16102.41	2366.32
676.	33.88	51.18	46.02	51.77	64.40	47.62			21188.56	3166.39

	64.97	60.75						
678.							28767.97	4344.41
	0.0	0.0	0.0	0.0	1.78	0.0		
	0.0	0.0						
680.							38566.20	4749.14
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
682.							47764.54	5549.58
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
684.							60764.54	6999.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
686.							75764.50	7749.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
688.							91764.50	8175.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
690.							108464.50	9000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
692.							127764.50	10425.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
694.							150164.50	12250.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
696.							176764.50	13650.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
698.							204764.50	14375.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
700.							234264.50	15500.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
702.							266764.50	17375.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
704.							303764.50	19525.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
706.							344864.50	21000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
708.							387764.50	21725.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
710.							431764.50	23000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
712.							479764.50	24650.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
714.							530364.50	25825.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						
716.							583064.50	27400.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0						

718.	0.0	0.0	0.0	0.0	0.0	0.0	639964.50	29175.00
	0.0	0.0						
720.							699764.50	30625.00

****

HH,AVPOOL ARE IN FT.
OUTFL,RESVOL ARE IN ACRE-FT.
ACQS, EVT ARE IN TONS

HH = 22.7 AVPOOL = 676.9 OUTFL= 0.0 ACQS= 2165160.0
RESVOL= 1566032.0 EVT= 2124056.0

ELEVATION-VOLUME-AREA RELATION AFTER 9 YEARS OF SEDIMENTATION

ELEVATION (FT,MSL)	SEDIMENT VOLUMES(ACRE-FT)						VOLUME (AFT)	AREA (ACRES)
650.							0.0	0.0
	63.34	69.43	60.64	45.57	11.00	0.02		
	0.0	0.0	0.0					
652.							0.0	0.0
	42.28	50.46	49.35	46.29	42.98	56.99		
	56.50	35.15	0.0					
654.							0.0	0.0
	59.87	74.13	77.05	72.28	42.40	65.45		
	68.51	89.95	90.81					
655.07(ZERO ELEVATION)							0.0	28.39
656.							29.57	35.33
	68.44	86.18	91.54	88.25	54.08	88.94		
	100.45	116.38	120.11					
658.							115.19	138.15
	80.45	102.26	109.71	107.21	67.04	112.57		
	130.23	154.36	169.21					
660.							582.17	328.54
	86.10	110.14	118.77	117.07	74.15	125.58		
	147.18	176.08	197.75					
662.							1429.37	428.02
	89.81	115.47	124.79	123.83	79.23	134.49		
	159.06	191.07	217.37					
664.							2294.25	445.16
	91.66	118.38	127.95	127.70	82.47	139.73		
	166.54	200.24	229.55					
666.							3210.02	635.91
	111.70	136.89	146.85	138.99	83.94	145.20		
	169.77	204.08	234.71					

668.							4837.90	1032.02
	119.12	153.25	161.95	160.58	98.78	167.01		
	191.71	214.94	232.48					
670.							7338.09	1388.54
	93.15	151.92	158.62	158.33	103.44	162.64		
	189.78	206.60	221.57					
672.							10392.05	1810.80
	83.90	138.57	141.82	144.05	96.90	146.14		
	174.51	186.18	198.68					
674.							14581.30	2282.46
	67.63	115.53	111.00	118.69	85.50	114.92		
	146.63	146.80	152.72					
676.							19521.89	3115.25
	33.29	51.11	45.95	51.65	64.14	47.42		
	64.57	60.58	60.89					
678.							27042.29	4329.87
	0.0	0.0	0.0	0.0	0.91	0.0		
	0.0	0.0	0.0					
680.							36841.38	4749.56
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
682.							46040.53	5549.79
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
684.							59040.53	6999.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
686.							74040.50	7749.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
688.							90040.50	8175.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
690.							106740.50	9000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
692.							126040.50	10425.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
694.							148440.50	12250.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
696.							175040.50	13650.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
698.							203040.50	14375.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
700.							232540.50	15500.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
702.							265040.50	17375.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
704.							302040.50	19525.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
706.							343140.50	21000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0					
708.							386040.50	21725.00

```
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    710.                                                                 430040.50    23000.00
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    712.                                                                 478040.50    24650.00
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    714.                                                                 528640.50    25825.00
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    716.                                                                 581340.50    27400.00
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    718.                                                                 638240.50    29175.00
            0.0        0.0        0.0        0.0        0.0        0.0
            0.0        0.0        0.0
    720.                                                                 698040.50    30625.00

*******************************************************************************************

    HH,AVPOOL  ARE IN FT.
    OUTFL,RESVOL  ARE IN ACRE-FT.
    ACQS, EVT  ARE IN  TONS

    HH =    21.6     AVPOOL =      676.7   OUTFL=      0.0   ACQS=      2690169.0
    RESVOL=       1418214.0   EVT=       2654889.0

                       ELEVATION-VOLUME-AREA RELATION AFTER      10 YEARS OF    SEDIMENTATION

  ELEVATION      SEDIMENT VOLUMES(ACRE-FT)                                    VOLUME    AREA
  (FT,MSL)                                                                     (AFT)    (ACRES)
    650.                                                                        0.0        0.0
           63.61      69.57      60.58      45.34      10.88       0.02
            0.0        0.0        0.0        0.0
    652.                                                                        0.0        0.0
           43.15      51.38      50.10      46.81      43.21      56.76
           55.36      33.23       0.0        0.0
    654.                                                                        0.0        0.0
           60.98      75.71      78.76      73.59      42.91      65.63
           67.59      85.62      87.52      31.70
    656.                                                                        0.0        0.0
           63.74      80.07      84.80      81.42      49.60      80.83
           89.81     100.39     104.91      81.00
    656.58(ZERO ELEVATION)                                                      0.0       20.72
    658.                                                                       83.43      96.81
```

	79.19	100.43	107.43	104.56	64.99	108.14		
	123.08	140.75	156.22	214.40				
660.							384.23	230.83
	84.75	108.17	116.50	114.80	72.65	122.22		
	141.13	163.74	187.60	265.90				
662.							1006.76	319.05
	87.21	111.88	120.55	119.13	75.78	127.45		
	148.30	171.87	197.98	286.22				
664.							1660.41	330.46
	90.23	116.27	125.30	124.54	79.96	134.23		
	157.40	182.59	211.94	309.38				
666.							2328.59	509.37
	110.90	135.46	145.07	136.43	81.38	140.09		
	160.45	186.09	216.70	318.11				
668.							3697.90	892.97
	118.67	152.60	161.15	159.65	97.67	165.53		
	188.73	210.95	226.56	315.94				
670.							5900.45	1241.49
	89.02	151.61	158.26	157.90	103.11	161.98		
	188.74	204.88	220.09	300.97				
672.							8663.88	1673.49
	80.18	138.29	141.49	143.66	96.59	145.54		
	173.56	184.63	197.36	268.17				
674.							12594.40	2170.01
	64.63	115.30	110.74	118.38	85.23	114.45		
	145.83	145.57	151.71	198.64				
676.							17343.93	3049.13
	32.67	51.05	45.88	51.55	63.94	47.27		
	64.29	60.32	60.59	75.45				
678.							24790.93	4311.63
	0.0	0.0	0.0	0.0	0.47	0.0		
	0.0	0.0	0.0	0.0				
680.							34590.46	4749.77
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
682.							43790.02	5549.89
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
684.							56790.02	6999.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
686.							71790.00	7749.99
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
688.							87790.00	8175.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
690.							104490.00	9000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
692.							123790.00	10425.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
694.							146190.00	12250.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
696.							172790.00	13650.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
698.							200790.00	14375.00
	0.0	0.0	0.0	0.0	0.0	0.0		

	0.0	0.0	0.0	0.0				
700.							230290.00	15500.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
702.							262790.00	17375.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
704.							299790.00	19525.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
706.							340890.00	21000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
708.							383790.00	21725.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
710.							427790.00	23000.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
712.							475790.00	24650.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
714.							526390.00	25825.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
716.							579090.00	27400.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
718.							635990.00	29175.00
	0.0	0.0	0.0	0.0	0.0	0.0		
	0.0	0.0	0.0	0.0				
720.							695790.00	30625.00

APPENDIX C

List of Variables Used in the Computer Program

Variables are listed in the order they appear in the programs

MAIN Program

PARAM	= index variable to indicate historical or generated water inflow data; PARAM = 1 for historical data, PARAM = 2 for generated data
NN	= number of years of simulation
DELTA	= lower limit of sediment volume used as a criterion for terminating sediment redistribution; its value is selected considering units used and accuracy desired.
Q(I)	= water inflow in week I
ASNL (KK,I,J)	= array of sediment characteristics for calculation of densities
KK	= submergence level (1=lower, 2=upper)
I	= (1=natural density, 2= compactim coefficient)
J	= sediment component (1=clay, 2=silt, 3=sand)
P(I,J)	= fraction of sediment component I in sediment zone J
ASSL(KK,I,J)	= adjusted values of ASNL(KK,I,J) for relative amounts of each components in each sediment component zone
X1,X2,X3	= fractions of incoming sediment that are component 1,2,3 (1=clay, 2=silt, 3=sand)
NUMBER	= highest value of index for discretized elevation-area-capacity array
ELEV(I)	= reservoir elevation in feet above M.S.L. at index I
AREA(I)	= original reservoir area in acres at index I
VOLUME(I)	= original reservoir volume in acre-ft at index I; also later used as reservoir volume adjusted due to sedimentation
AAREA(I), AVOL(I)	= storage locations for storing AREA(I) and VOLUME(I)
IRESTY	= numerical designation of the type of reservoir (types: I, II, III, IV)
EMM,ENN	= coefficients in empirical area-increment method
BETA	= trial incremental fraction of trapped sediment that completely fills the reservoir to the new zero elevation

NTIYR = number of intervals in a year (=52 when week is used as the interval)

NTI = number of weeks at the end of which adjustment for compaction and slump are made

AMPC(I) = weekly pan evaporation coefficient for week I

GGAMA = overall specific weight (lbs/ft^3) of incoming sediment

NRDERI = order of Markov model used for water inflow time series model

PROB = discretized cumulative distribution for independent stochastic component

INFISC = array of independent stochastic component for cumulative distribution of water inflow time series

RHOIN(I,J) = correlation coefficient of water inflows of lag I for Jth week

TMEANI = array of weekly means for water inflow

TSTVI = array of weekly standard deviations for water inflow

TMEIN = overall mean of weekly means for water inflow

TSDIN = overall standard deviation of weekly means for water inflow

RANU = Values of seed number for random number generation; also used later as random numbers from uniform distribution

XYX1,XYX2,XYX3 = starting values used in Markov model

SEDISC = array of independent stochastic component for cumulative distribution of sediment inflow time series

TMEANS = array of weekly means for sediment inflow

TSDVS = array of weekly standard deviations for sediment inflow

TMEANE = array of weekly means for pan evaporation

EVISCD = array of independent stochastic component for cumulative distribution of pan evaporation time series

TSTDVE = array of weekly standard deviations for pan evaporation time series

DHEAD(I) = design pool elevation in the reservoir at the discretized index I

IUSD(I) = spillway discharge in acre-ft corresponding to DHEAD(I)

IMCD(I) = conduit discharge in acre-ft corresponding to DHEAD(I)

DAMHT = height of dam used in calculating capacity of reservoir

IDS = subscript of water surface elevation used in delineating the upper and lower densities

ELPREO(I) = reservoir elevation during week I of operation

HH = average head in reservoir during correction period

NUOC = number of volume area correction periods

ACQI = accumulated water inflow (acre-ft) in correction period

ZELEV = zero elevation = elevation at the top of sediment fill at the dam

XSAVE = temporary location for storing incoming sediment load when it is too small; sediment distribution ommitted for the current period and this small value is added to the sediment inflow of the next period.

QI(I) = water inflow (acre-ft) during week I

QS(I) = sediment inflow (tons) during week I

QE(I) = pan evaporation (inch) in week I

Subroutine CALCMA

ZR(I,J),ZR1(I,J) = correlation coefficient of water inflows of lag I for Jth week

ZD(I) = standard deviation of stochastic component of water inflow for week I

R(I,J) = Markov model (of order I) coefficient for Jth week

DUM(I) = intermediate location for ZD(I)
(other variables in this subroutine are defined earlier)

Subroutine INPUTS

J1,J2,J3 = previous week, second previous week and third previous week of the year

EPSILO = random number which is the independent stochastic component of reservoir inflow series

CORRIN(I,J) = coefficient of Markov model of order I for week J

Z = generated number from the given distribution, from which periodicity in mean and standard deviation had been removed

E = random number which is independent stochastic component of sediment inflow time series

EATA = random number which is independent stochastic component of pan evaporation time series (other variables in this subroutine are defined earlier)

Subroutine OPERAT

THEAD = operation head at the beginning

AVSTO = reservoir storage (acre-ft) corresponding to THEAD; also used as average storage adjusted for outflow and evaporation

TSTOR = total storage (acre-ft) = Inflow + Av. storage

VP = storage (acre-ft) required as per current operation head

EXSTOR = storage (acre-ft) in excess of required storage

OUTFL = total outflow (acre-ft)

ATSTOR = average of storages at the beginning and end of the current period (used as an intermediate step to calculate AVSTO)

AHEAD = average reservoir elevation corresponding to ATSTOR

SPILL = spillway discharge capacity corresponding to AHEAD

TDISCA = total (spillway + conduit) discharge capacity corresponding to AHEAD

CHVOL = storage in reservoir at the end of current period

RESUR = reservoir surface area (acres)

HEAD = reservoir elevation corresponding to net storage (=total storage - evaporation)

(Other variables in this subroutine are defined earlier)

Subroutine EVAPCO

QER = evaporation (acre-ft) corresponding to reservoir surface area RESUR (defined in OPERAT)

(Other variables in this subroutine are defined earlier)

Subroutine SEDCOM

EVT	=	volume (acre-ft) or weight (tons) of sediment trapped in the reservoir
YR	=	adjusted age of sediment for use in computing densities of deposited sediment
AVPOOL	=	average pool elevation in the reservoir during the correction period
SPWT(K,I,J)	=	density of sediment in level K, zone J and I years old
S	=	relative depth used in empirical area-reduction method; also used to represent temporary variables in various sections
FP(II)	=	normalized relative sediment area at elev. index II; also later used as temporary storages for excess sediment volumes in redistribution calculations for slump
OZELEV	=	temporary storage location for zero elevation ZELEV
DEAVOL	=	volume of sediment below zero elevation
AA,B,CD,FKA	=	variables used for temporary storages in various calculations
K2	=	elevation index which is just below zero elevation
FPO	=	difference between new zero elevation and previous zero elevation
FKA	=	normalized relative sediment area at zero elevation
AZS	=	reservoir area at zero elevation
AZSS	=	modified reservoir area at zero elevation
HP(J)	=	sediment area at elevation index J; later used as sediment volumes between elevation indices J and J+1
V(I,J)	=	array of uncompacted or compacted sediment volume of age I between ELEV(J) and ELEV(J+1)
YYY	=	cumulative volume of incoming sediment of component J (cumulative on J,J=1,2,3); also later used as temporary storages
XI(J)	=	fraction of incoming sediment that is component J (J=1 for clay, J=2 for silt, J=3 for sand)

X(I,J)	=	elevation index corresponding to sediment zone J (j=1 for clay, J=2 for silt, J=3 for sand) in correction period I; also later used as the total volume of compacted sediment in sediment zone J in correction period I
USVOL	=	uncompacted sediment volume between elevation indices K2 and K2+1
NREC	=	number of volume-area correction period (in reverse order to NUOC earlier defined)
IJ1,IJ2,IJ3	=	elevation index corresponding to sediment zone of clay, silt and sand respectively in any correction period
A,AA,B,HH,R	=	temporary storages used for various calculations in compaction of sediment
IIK2,SSS,RRR,KPI,AA,BB	=	temporary storages used for various calculations in sediment slump correction
TT	=	reservoir surface area at zero elevation
S,SS,R,RR,B,B1,W,IK2,A	=	temporary storages for various calculations in sediment redistribution
IFLAG	=	index variable; IFLAG=1 when incoming sediment volume is too small; IFLAG=0, otherwise
IY	=	interval at the end of which output for the values of zero elevation, sediment volumes and adjusted volume-area relationship is printed

(Other variables in this subroutine are defined earlier)

APPENDIX D

Available Water Inflow, Sediment Inflow and Evaporation Data for the Coralville Reservoir

Table D1 Weekly Flows in Iowa River in Acre-ft (1234 m^3), Week No. 1 ≡ 1 October-7 (Source: Water Supply Bulletins of Iowa Geological Survey, Iowa City, Iowa)

Year	1	2	3	4	5	6	7	8	9
Week No.	1939	1940					1945		
1	544.1	1682.0	11178.3	24909.4	11527.4	10229.7	10704.3	55922.3	3190.0
2	679.5	1690.9	53436.4	33099.3	9336.0	9790.5	11050.0	15166.5	3183.7
3	721.7	1504.2	34213.0	21252.3	8273.5	9107.3	7764.9	11623.6	3403.5
4	742.7	1374.8	35808.2	16298.0	8020.7	8005.6	6696.3	18106.9	2690.1
5	1191.6	2017.5	35626.5	15431.1	7307.3	7343.5	6091.3	30363.3	2503.5
6	1603.6	2423.7	65930.0	12439.5	7131.8	6368.1	5446.7	34536.2	6069.2
7	1648.7	2939.6	42843.6	15896.3	9019.6	5911.3	5292.1	23488.6	7537.2
8	1535.9	8705.9	28019.8	12392.1	8256.9	5880.5	5970.8	20310.6	5431.5
9	1499.4	7496.2	21253.8	10348.2	7233.7	5638.6	4519.1	17809.3	5694.0
10	1482.3	3991.5	18443.6	7161.6	6623.3	4884.8	4911.4	14744.0	5353.6
11	1563.5	5312.1	14235.2	8349.5	9447.9	4893.9	184134.4	12833.1	6566.7
12	1268.8	3089.0	13332.7	7513.1	5158.0	3826.4	3960.7	12258.6	7821.3
13	1229.1	4057.5	21208.1	7381.1	3804.4	3507.2	3133.1	6324.6	6808.8
14	735.8	9171.9	13811.0	10695.1	3297.2	3023.0	2593.8	9097.9	5576.2
15	574.1	8718.9	11994.1	8898.4	3346.2	3235.6	8252.6	4593.8	4442.2
16	557.8	9459.2	14663.7	8696.5	3222.8	2987.3	174072.6	5780.2	4571.2
17	544.3	6206.4	22694.7	6430.7	3312.6	3088.2	20675.7	10805.2	3895.8
18	387.7	4683.7	36715.3	5959.6	12397.9	3357.4	12532.5	9324.6	2896.3
19	93.1	4339.0	34817.6	21102.1	15633.2	3139.8	9498.8	7552.6	2123.6
20	200.7	19239.1	24767.0	45119.5	8404.5	3057.6	53009.2	6525.1	1610.3
21	286.1	17982.8	16977.7	23133.7	5344.1	13334.4	37807.7	9138.2	1424.4
22	792.5	7621.6	18234.0	77509.6	22379.9	21877.4	18234.0	33360.3	3509.9
23	4926.0	18155.8	27869.7	39009.2	17789.4	28227.2	21579.9	14646.9	29515.9
24	9484.9	19253.7	30590.5	21640.4	11842.9	37034.6	48610.2	12045.8	93469.1
25	22993.6	32261.2	45770.0	50056.1	54958.8	65651.3	78372.4	31783.9	20566.4
26	12143.7	74905.4	53097.2	49708.1	40543.1	111547.5	60749.9	40662.4	122526.4
27	11807.9	16935.7	38292.2	41628.1	31998.4	71952.1	49612.6	41808.1	107824.3
28	8555.2	21428.0	28694.7	32725.4	29120.5	57136.8	31744.4	38220.6	61257.4
29	6426.3	17107.7	20973.8	37441.6	46066.6	58556.1	21286.1	88474.3	28694.7
30	4550.0	15012.9	16298.8	21683.5	57789.7	106782.9	17087.9	102909.9	21842.4
31	5365.1	10251.4	23029.2	30774.0	60883.7	73713.9	12898.2	75786.0	15393.3
32	4983.2	6368.2	30430.2	30916.6	57711.1	52301.5	17966.9	48517.6	24853.9
33	3361.9	4463.5	43486.5	28407.7	78764.1.	21989.4	34859.1	30558.2	34423.9
34	4591.5	3457.4	35755.1	68549.5	71954.4	67269.4	20087.5	24695.7	28945.4
35	3631.1	2410.3	21802.8	32785.5	299390.3	58974.9	24362.9	30199.8	20036.3
36	6408.5	70401.8	39474.3	42986.6	126156.2	68831.4	30489.5	48017.8	12791.4
37	6194.2	26807.9	86056.1	35628.1	45556.2	74532.4	23414.1	246678.3	11089.6
38	5731.7	24813.8	56067.7	42166.5	147049.3	62951.3	15834.5	186011.1	10776.4
39	9689.2	15251.6	36989.4	31774.1	99420.4	42108.9	39847.9	227657.5	10093.9
40	6345.3	27812.4	35730.1	23376.9	51105.7	32100.0	34075.0	180834.1	9263.5
41	5687.2	15462.8	26859.9	18310.1	42943.1	27583.2	30658.7	120073.9	13278.3
42	5378.9	9807.9	29086.9	125679.2	30628.6	19484.5	19741.5	78878.1	9436.8
43	5121.9	7855.1	21568.4	68048.1	22177.7	15184.9	14174.2	46426.2	10594.0
44	8216.1	6174.3	30811.3	27925.8	22387.1	12651.5	13765.0	26384.1	11595.2
45	10230.2	3384.6	42249.9	45856.9	18328.5	9308.1	18209.4	17913.6	8667.8
46	7795.5	2910.7	16486.8	26728.3	17156.4	7950.9	9877.2	11059.1	3960.2
47	7611.3	2931.8	12806.9	24176.6	11467.7	22754.9	8188.8	7939.4	3471.0
48	6423.2	2646.0	13582.0	14840.6	9384.1	36781.9	8073.7	6439.0	3139.0
49	9476.8	1662.5	34891.7	18584.0	17177.7	14648.8	7298.6	5723.4	2795.6
50	3441.9	21218.2	33764.7	27063.8	14668.4	10800.6	5302.2	4741.0	2686.4
51	3361.7	22050.7	52175.8	33572.0	11275.2	8324.4	37703.8	3780.8	1692.3
52	2399.9	11371.5	34549.6	16124.1	11460.7	6568.9	16309.7	3615.9	1392.3

Table D1. (cont'd.)

Week No. / Year	10	11	12	13	14	15	16	17	18
			1950					1955	
1	1385.5	1335.1	9784.4	25836.6	2965.6	1777.0	15146.5	1053.4	5938.2
2	1111.4	938.6	14111.8	15035.9	2503.0	1488.5	10372.4	1367.1	2557.9
3	1076.8	1272.5	6561.9	17082.4	2052.8	1116.5	19282.8	1606.0	1593.8
4	1281.5	1338.7	7635.4	15907.6	1702.9	799.9	33340.1	1100.9	985.3
5	911.3	1179.2	5444.2	14377.6	2220.6	854.1	52091.9	4664.6	843.0
6	944.4	1359.8	4038.6	28885.4	2241.7	799.9	44807.9	2058.1	1574.9
7	1743.5	1382.9	3196.1	19588.6	2087.5	1116.0	27380.5	1284.5	1100.8
8	2243.3	1529.8	2835.8	11494.3	2290.5	1613.8	16335.3	1497.8	1009.6
9	2477.0	1669.2	2643.1	18075.8	2323.3	1706.1	12595.3	1613.8	1154.4
10	3057.3	1550.5	2198.2	14176.1	3420.2	1872.2	10940.7	1568.7	1209.9
11	2101.5	1416.9	1803.4	11940.8	2837.9	2128.5	9624.4	1599.5	1555.0
12	1790.4	1083.9	1429.4	13213.9	2253.7	1818.8	8618.4	1024.5	1239.7
13	1999.5	1420.6	1367.8	8987.8	2527.8	1841.0	7172.0	888.0	1299.2
14	1889.5	1345.8	1308.4	6940.9	2582.8	1257.8	6665.7	797.7	1200.0
15	1853.6	1156.5	1196.1	6371.6	2505.8	1101.5	6489.7	692.1	1134.5
16	12555.0	1168.0	1358.9	7374.8	2296.6	1141.3	5983.9	696.5	1102.8
17	11545.5	2778.6	1383.3	6946.7	2157.2	1228.5	8853.5	941.4	1011.6
18	23928.5	2810.0	1798.3	18836.2	5365.2	952.6	7092.5	923.4	936.2
19	8090.8	1239.7	1612.1	39856.0	6767.2	862.9	5398.8	898.8	833.1
20	4618.1	816.2	1120.2	20575.5	3783.6	815.8	4501.5	788.8	7061.1
21	3849.1	12666.0	788.7	31048.6	6801.4	448.3	4554.0	476.7	2786.8
22	3648.1	10419.7	4708.4	25018.2	23887.5	663.0	4163.2	271.1	3203.3
23	14703.8	2768.6	33812.5	28023.3	26073.5	2494.8	6788.9	384.1	11305.8
24	48726.4	6358.3	84154.6	25030.3	62280.9	2997.3	44240.1	597.7	10869.4
25	110421.3	160427.3	48132.8	20996.0	19964.9	3037.7	33894.4	6216.7	4234.7
26	37846.1	36080.0	20060.4	110640.6	22451.9	3346.3	21115.3	5410.8	3986.8
27	45698.4	40543.1	12480.2	75061.8	33072.7	3675.6	20948.2	4074.2	3225.1
28	63646.8	46980.6	104506.9	59374.2	27917.4	5482.4	13788.1	6117.2	3867.8
29	39282.4	33775.7	181691.9	85372.4	31658.4	3255.4	11774.3	8365.5	4869.4
30	20315.3	17303.6	151291.3	64800.9	27644.4	5830.2	13025.9	9636.7	4679.0
31	22960.8	9611.2	98920.2	53730.6	23642.1	4936.1	14700.7	3718.3	4085.9
32	15912.7	10695.5	69598.1	52944.2	21428.0	6744.2	15992.2	1896.0	3401.7
33	9202.1	15421.4	88238.8	28772.0	33495.1	13427.5	24039.5	891.2	3066.4
34	6793.1	61550.5	82015.4	20855.6	38622.4	30174.2	14135.4	2880.6	3219.2
35	6509.0	29611.0	37675.2	20983.6	23697.2	13884.5	14916.2	4568.4	3881.6
36	6173.6	30737.4	32278.4	32432.1	24682.9	7719.9	10095.6	14414.4	12680.3
37	9856.0	18874.8	29500.8	40312.0	27998.1	6667.7	7847.9	3810.7	13610.6
38	8822.5	100896.9	122544.5	23586.7	18916.5	41958.5	10182.6	5124.8	27252.9
39	8389.2	196710.3	44908.4	23145.7	34554.3	36836.0	10322.0	6705.7	34333.9
40	11033.3	90312.8	48762.4	38791.8	22229.1	64446.9	9219.4	5904.2	14780.8
41	18917.4	51735.3	37027.8	30470.2	23625.0	71656.3	8139.9	5501.6	59583.4
42	12938.9	16559.1	76575.1	27190.3	28882.3	91830.4	7045.4	5137.3	27947.1
43	8178.7	11267.8	85406.4	29772.1	18702.2	27659.3	8121.1	5148.6	26284.1
44	7803.7	9524.3	43019.3	33940.4	13222.5	17594.5	22179.6	5822.4	29464.4
45	7244.2	8917.2	28496.8	22406.1	11442.9	12847.6	10344.7	6638.9	10280.3
46	3557.5	5947.3	18149.2	12811.4	9545.4	10506.5	7733.3	5790.0	11684.6
47	2768.7	4555.0	11978.1	8975.4	10307.0	6842.0	4592.8	11995.5	20826.4
48	2609.5	4023.5	13336.4	6957.1	9485.8	5750.3	3454.4	4378.5	7084.9
49	2575.0	3492.1	17921.9	5763.7	5596.8	6671.2	2724.6	7985.4	4657.2
50	1823.1	2883.4	46138.1	4944.4	4094.5	34554.3	3056.5	3503.6	3800.3
51	1712.9	1751.9	28369.7	4070.3	2637.6	92930.9	2802.8	5157.1	10667.1
52	3322.3	1669.4	28919.2	3414.4	2079.3	26799.8	1140.4	8179.2	5720.3

Table D1. (cont'd.)

Week No.	Year 19	20	21	22 (1960)	23	24	25	26	27 (1965)
1	3893.6	42307.4	6487.9	4901.1	4105.8	21179.5	12376.8	9933.2	7586.8
2	3758.7	14068.7	3373.9	3453.2	20013.2	27034.7	10690.9	6765.6	6041.6
3	3072.4	9629.7	3161.6	4835.7	9998.7	14290.9	6311.4	4260.5	4585.8
4	2394.0	6791.4	8953.4	16681.0	7876.4	9903.5	5430.7	3901.5	4899.2
5	2187.8	8759.0	8441.6	8604.3	32568.6	11525.9	5611.2	6573.2	15276.7
6	2513.1	6240.0	5615.2	6372.9	21520.6	14608.2	4706.8	8217.5	19537.2
7	6047.6	4990.4	4843.6	5438.7	23008.2	4425.1	4046.3	11042.0	40348.8
8	2985.1	4437.0	5166.9	5262.1	16581.8	2465.5	3808.3	13916.0	72138.8
9	3429.4	4133.6	21001.0	14632.0	31477.7	10310.1	3314.4	8638.0	107960.1
10	3231.1	3824.1	18446.3	8737.2	34651.2	12083.3	2929.6	5793.7	102346.9
11	4276.4	15736.8	12872.7	7804.9	40938.8	9540.5	2671.7	4770.2	67933.8
12	4768.3	7414.2	13745.4	6628.8	43279.3	8429.7	3024.8	4256.5	33699.1
13	5157.0	4661.2	12545.4	5256.2	31239.6	7715.7	2778.8	3905.5	37725.6
14	3907.4	4185.1	10389.4	4919.0	24495.8	7239.7	2645.9	3909.4	26595.0
15	6228.1	3173.6	9431.4	4443.0	18089.2	6470.1	2596.4	3530.6	21937.2
16	7275.4	2796.7	8876.0	3312.4	19438.0	5942.5	2602.3	3477.0	28720.6
17	3590.1	3887.6	20945.4	3669.4	16462.8	3455.2	3518.7	2489.3	23008.2
18	4790.1	2955.4	12813.2	3590.1	15471.1	1493.6	2893.9	2469.4	20112.4
19	4324.0	2687.6	99371.8	3421.5	12515.7	1511.4	2338.5	2390.1	19180.1
20	4899.2	1993.4	37487.6	3600.0	10988.4	3788.4	1725.6	3451.2	23444.6
21	3669.4	2043.0	27768.6	2320.7	9084.3	4284.3	1088.9	2320.7	27927.2
22	3173.6	1884.3	16879.3	1795.0	9758.7	4066.1	1069.1	2102.5	28859.5
23	2459.5	1963.6	13904.1	2052.9	14677.7	4502.5	1106.8	10076.0	32548.7
24	1725.6	2459.5	11821.5	16462.8	18049.6	3748.8	1342.8	4581.8	28462.8
25	30009.9	28661.1	12158.7	69421.4	14261.1	3371.9	1553.1	3054.5	21223.1
26	13592.7	53395.0	9758.7	46393.4	12039.7	2578.5	2465.5	26281.0	13249.6
27	9001.0	29137.2	7715.7	103993.2	11781.8	4304.1	2479.3	3252.9	8826.4
28	7428.1	91140.4	7398.3	95642.8	23008.2	6406.6	2727.3	43338.8	33203.3
29	6228.1	156535.4	8350.4	66426.4	102842.9	7676.0	2856.2	25983.4	37487.6
30	6458.2	113613.1	188429.6	64998.3	184661.0	6208.3	2782.8	26578.5	18981.8
31	19057.2	40621.5	169427.9	71761.9	145586.6	26935.5	2824.5	45024.8	15094.2
32	13279.3	23682.6	61943.8	36238.0	98459.4	53355.3	3145.8	55933.8	16700.8
33	9405.6	25904.1	80727.1	36099.1	64403.3	566478.8	4476.7	46016.5	16462.8
34	17238.3	41871.0	46809.9	35127.2	38419.8	151100.6	3824.1	39669.4	39847.9
35	6343.1	26042.9	72833.0	23127.2	30109.1	26538.8	3215.2	73983.4	42545.4
36	5740.2	30644.6	147689.0	17514.0	38737.2	15679.3	13023.5	219173.3	36833.0
37	5071.7	52978.5	64740.4	15173.5	39927.2	11563.6	10919.0	204098.9	30565.3
38	3736.9	45064.4	65890.8	13388.4	24376.8	12065.4	10857.5	108297.4	27332.2
39	17609.2	54545.4	64264.4	11609.2	59246.2	23095.5	13467.6	83087.5	24436.3
40	36773.5	31200.0	33381.8	31418.2	51312.4	39649.6	18922.3	37626.4	22750.4
41	33758.6	14360.3	27609.9	21104.1	37328.9	33128.9	23444.6	23682.6	24952.0
42	12706.1	9592.1	27094.2	13646.3	20449.6	30604.9	19617.3	16542.1	60555.3
43	14142.1	36924.3	17950.4	9233.0	15332.2	16938.8	14386.1	23444.6	58909.0
44	23682.6	22869.4	14033.0	9873.7	15619.8	14390.1	10450.9	57699.1	52720.6
45	59234.7	13590.7	23047.9	7959.7	31715.7	17153.0	7154.4	61943.8	33917.3
46	32072.7	9488.9	13225.8	11504.1	123966.7	16710.7	13622.5	31418.1	112482.5
47	23206.6	7083.0	10999.2	15139.8	97864.3	10155.4	43219.8	19081.0	100006.4
48	17742.1	6291.6	7358.7	25824.8	40185.1	9318.3	19989.4	18636.7	38380.1
49	15796.3	5293.9	6293.5	19804.9	24119.0	13785.1	14515.0	22552.0	31636.3
50	28780.1	4724.6	5631.3	9467.1	15719.0	22452.9	18981.8	48158.6	20271.1
51	12670.4	3504.8	5720.3	6420.5	12803.3	31557.0	14027.1	21500.8	15740.8
52	56661.8	4026.4	7666.1	4536.2	11085.6	17976.2	7102.8	11700.5	16684.9

Table D1. (cont'd.)

Year / Week No.	28	29	30	31	32 1970	33	34
1	12799.3	4115.7	4264.5	20132.2	6908.4	3826.1	22373.5
2	8640.0	3298.5	3996.7	11269.1	5127.3	3215.2	23424.8
3	6944.1	3125.9	4881.3	12765.6	6105.1	3356.0	16780.1
4	8604.3	3425.5	3965.0	12364.9	21233.0	2556.7	20687.6
5	6585.1	2743.1	3655.5	6235.4	17347.4	2649.9	17236.3
6	4401.3	2358.3	3822.1	7245.6	19572.9	2402.0	21441.3
7	3691.2	2737.2	7140.5	6493.9	28863.4	2039.0	39173.5
8	3203.3	2653.9	11442.6	8251.2	47385.1	2158.0	30485.9
9	2731.2	2782.8	10827.8	10083.9	27014.8	2402.0	21540.5
10	2647.9	5381.1	8854.2	8826.4	26915.7	2572.6	41831.4
11	2596.4	4478.7	6737.8	12115.0	23543.8	5575.5	52165.2
12	3310.4	3697.2	5984.1	9411.6	23266.1	4770.2	65276.0
13	2463.5	3607.9	6862.8	7872.4	22135.5	3917.4	61666.1
14	2179.8	2731.2	6708.1	7354.7	22393.4	5404.9	331094.6
15	2413.9	3280.7	5605.3	5906.8	21699.1	5492.2	535913.6
16	1989.4	2778.8	6287.6	4885.3	17137.2	5762.3	450967.4
17	2437.7	2955.4	9461.1	4439.0	16204.9	8078.7	22552.0
18	2290.9	2336.5	8152.1	4185.1	14697.5	8735.2	19993.4
19	2090.6	2257.2	4938.8	3488.9	14023.1	6696.2	23067.7
20	1406.3	1499.5	3649.6	3036.7	9580.1	4443.0	76165.2
21	1257.5	1402.3	9381.8	3645.6	8687.6	4324.0	39471.0
22	9143.8	4651.2	25943.8	3895.5	8568.6	3689.3	56330.5
23	5285.9	7180.2	10790.1	3778.5	7735.5	3074.4	68826.4
24	3556.4	4387.4	6019.8	4379.5	6763.6	2796.7	67239.6
25	8727.3	3008.9	5533.9	7313.0	6228.1	2231.4	112799.8
26	3352.1	2249.3	6168.6	8459.5	44608.2	2409.9	25586.7
27	2691.6	1953.7	21084.3	17890.9	108058.9	3332.2	24198.3
28	2943.5	3723.0	22413.2	71226.4	92628.0	38578.5	67973.5
29	4720.7	7547.1	17196.7	30307.4	43438.0	40066.1	78842.9
30	14459.5	5127.3	98776.8	17930.6	106274.2	32866.1	109447.8
31	9897.5	4446.9	149731.9	22710.7	82234.6	21441.3	105183.3
32	7233.7	10675.0	86142.0	24416.5	50479.3	13902.1	65414.8
33	7392.4	7733.5	80290.8	21342.1	48119.0	10655.2	73844.6
34	7685.9	8205.6	60178.5	20786.8	29712.4	8735.2	58135.5
35	7473.7	19933.9	47603.3	22968.6	22155.3	24277.7	204098.9
36	6027.8	16959.7	46869.4	18426.4	18366.9	22452.9	129718.8
37	4901.2	9594.0	45322.3	13836.7	16145.4	23940.5	76105.7
38	5648.9	7281.3	39887.6	56259.1	14261.1	55973.5	93877.6
39	4133.6	6257.8	35561.6	85745.3	22510.4	29514.0	89057.7
40	3423.5	5659.8	30862.8	49130.5	27867.7	19160.3	44489.2
41	15092.2	4671.1	27927.2	37527.2	18545.4	19644.6	104846.1
42	70889.2	4764.3	102386.6	22928.9	17414.9	34274.3	99153.6
43	71761.9	4954.7	61388.4	16899.2	30664.4	93302.4	59067.7
44	33540.5	9421.5	46790.0	16125.6	15197.3	125335.3	63034.7
45	25269.4	20112.4	112621.3	11440.6	12345.1	41057.8	243788.2
46	13658.2	9296.5	198108.8	7775.2	24654.5	24753.7	168846.8
47	9197.3	11178.8	221553.4	6979.8	35444.6	25586.8	28403.3
48	7025.4	32033.0	117659.3	8532.9	12440.3	36257.8	18743.8
49	7812.9	14804.6	98142.1	6136.9	9052.5	34869.4	17276.0
50	12537.5	24799.3	44409.9	32576.5	7457.8	41117.3	19775.2
51	6967.3	11256.2	31715.7	17952.4	5744.1	103437.9	13348.7
52	5329.6	6884.6	29157.0	9875.7	4587.8	57580.1	9984.8

Table D2. *Weekly Sediment Load* in Iowa River in Tons (907.18 kg), Week No. 1 ≡ 1 October-7
(Source: U.S. Army Corps of Engineers, Rock Island District, Rock Island, Ill.)

Year	1	2	3	4	5	6	7
Week No.	1957			1960			
1	469	24008	2044	588	684	15397	896
2	354	2447	249	316	43547	10537	1850
3	179	1137	1480	1342	3110	2742	799
4	120	519	12875	18160	1791	853	501
5	86	2105	4763	1621	34001	1324	292
6	83	1036	525	522	31745	2796	211
7	175	397	380	184	9987	2491	254
8	141	574	233	251	14257	1333	554
9	127	131	41566	15883	41748	675	151
10	126	356	9463	626	20547	405	129
11	645	4527	5357	814	55395	332	71
12	910	543	9219	365	26212	194	192
13							314
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26	11309	38616	1529	37942	1596	280	
27	1477	13357	1083	300688	1382	6384	88
28	902	261433	1005	130929	21846	26886	444
29	750	108885	1266	38095	143799	176020	752
30	861	529745	237932	54039	126146	30650	506
31	23007	10643	49182	20680	26096	8664	4715
32	8180	6119	22062	12207	24871	2118	17470
33	1975	16981	49229	17861	22271	10323	4396
34	1507	120122	11447	32633	14893	7208	4899
35	728	16464	131874	4963	9271	59433	12768
36	2683	60049	76518	2410	66680	25330	16760
37	3006	212946	32903	3241	39151	44510	38130
38	2324	43144	84546	1325	27227	12595	11286
39	74148	139842	40320	1534	105655	5660	12708
40	224190	14464	18096	110976	47061	5862	3904
41	44176	4003	13565	17883	37217	10020	2627
42	4742	4067	35633	4757	8059	6814	51030
43	27059	172580	5165	1979	6078	3766	281230
44	26313	11528	4230	6441	12338	15923	11144
45	111590	15767	39975	2486	84853	17600	31055
46	36587	4857	4355	8991	65855	40510	34900
47	37423	2973	3997	27889	37879	29800	4597
48	20280	1280	1676	33753	28704	6381	1279
49	32833	2576	985	15510	10185	12683	6453
50	23856	1800	650	2159	5132	2583	893
51	4258	436	913	1086	5077	1138	813
52	51202	866	1704	563	3141	1354	870

Table 12. (cont'd.)

Year	8	9	10	11	12	13	14
Week No.		1965					1970
1	7423	38839	508	690	232	4109	173
2	5225	71198	4592	565	97	33728	1429
3	7923	27372	5590	1052	179	14251	1152
4	8342	129130	3918	751	319	7889	308
5	1483	66331	1388	535	245	17337	2076
6	450	33572	647	2039	3655	23320	283
7	248	19191	237	1664	302	27008	122
8	194	13558	276	913	359	19188	46
9	202	11327	214	292	277	10174	49
10	193	7025	186	243	122	7583	255
11	151	8485		270	120	3703	41
12	105	9302		282	4135	1512	1634
13	148	6993			291	3784	77
14					238	652	5
15					110	30146	26308
16					169	1504	19
17					186	60800	198
18					132	92749	1144
19					188	51009	310
20					49	86901	39
21					73	23011	26
22					44	4015	26
23					15121	78320	3517
24					12327	78927	5314
25					26869	88705	900
26			152787	15768	13129	16996	702
27	5665	741	65821	6660	2382	26038	92642
28	3738	1603	47010	4411	1455	42166	10709
29	27558	109349	44137	4549	1084	21413	7000
30	2498	106173	22856	10583	26341	121918	46004
31	196025	36495	68461	5073	20345	25398	14260
32	347186	21284	32674	3495	8929	35519	2836
33	42704	11156	10628	54905	68412	22135	2566
34	128128	11754	16237	129928	17283	16183	1491
35	128849	8509	5940	128880	16784	14159	1330
36	21787	4409	196342	48643	27686	58067	1407
37	4270	82087	188336	11698	63385	31554	6361
38	2079	160606	22921	7264	244135	32955	2754
39	99309	172683	90623	21218	79210	89679	18536
40	70215	31617	216606	2640	42300	78219	20376
41	59003	130307	401373	1298	22068	103017	4210
42	10438	272140	152568	4322	33354	468996	14077
43	38204	34830	64990	6997	70116	8809	37632
44	107110	38525	106106	1008	45833	5813	6619
45	196097	34852	20193	52858	54534	15409	59950
46	62334	6428	27068	13231	160817	6006	3733
47	6041	4368	35357	3590	26166	2586	3749
48	2036	37706	11977	5289	9248	1949	922
49	1271	3239	2381	1473	30302	2952	751
50	845	1758	10068	4450	6339	1562	3808
51	808	1135	5337	33712	2198	2159	694
52	1621	4788	1199	13115	5646	1138	590

Table D3. **Weekly Pan Evaporation in in (2.54 cm), Week 1 ≡ 1 October-7**
(Source: U.S. Weather Bureau, Climatological Data)

Year	1	2	3	4	5	6	7	8	9	10	11
Week No.	1949	1950					1955				
1		0.92	0.76	0.82	1.09	0.62	0.65	1.31	0.88	0.88	0.33
2		1.01	0.72	0.80	1.04	1.14	1.09	1.27	0.97	0.93	0.67
3		1.13	0.53	0.86	1.16	0.79	0.77	0.71	0.29	0.73	0.71
4		0.67	0.34		0.72	0.73	0.61	0.79			0.34
27	0.89	0.65	0.92	0.73	1.06	1.44	1.55	0.84	1.19	0.87	0.76
28	0.93	0.48	0.86	0.83	1.69	0.89	1.17	0.91	1.40	1.22	0.80
29	1.11	0.97	0.78	1.18	0.92	1.78	1.49	1.22	0.86	0.81	1.66
30	0.73	0.71	1.67	0.58	0.87	1.56	0.87	1.72	1.27	1.47	1.22
31	1.34	1.55	1.09	1.04	1.45	1.93	0.68	1.66	1.39	1.57	1.27
32	1.45	1.06	0.94	1.54	1.53	1.07	1.82	0.87	1.67	1.25	1.11
33	1.25	1.56	1.12	1.18	1.34	1.80	1.71	1.02	1.94	1.16	1.09
34	1.18	1.38	1.54	1.65	1.13	1.53	1.64	1.30	2.05	1.43	0.85
35	1.41	1.59	1.72	2.11	0.96	1.59	1.52	1.73	1.85	1.64	1.11
36	1.94	0.77	1.75	1.41	1.90	1.27	2.10	0.72	1.82	2.03	1.19
37	1.72	1.32	1.40	2.37	1.88	1.62	2.46	2.18	1.24	1.36	1.16
38	1.18	1.05	1.48	1.72	1.96	1.57	2.08	1.51	1.85	2.01	1.38
39	2.14	1.14	2.07	2.20	2.41	2.15	2.72	2.18	1.52	1.16	1.30
40	1.48	1.41	1.96	1.80	1.81	2.25	1.78	2.32	1.39	1.85	1.93
41	1.57	0.73	1.08	1.48	2.45	1.97	2.26	2.18	1.16	1.97	1.08
42	1.14	1.38	1.98	2.00	1.44	1.87	2.44	1.65	1.67	1.72	2.07
43	1.42	1.44	1.80	1.72	1.82	2.40	2.03	1.73	1.21	1.49	2.04
44	1.57	1.70	1.03	1.41	1.45	2.25	1.77	2.09	1.73	1.23	1.42
45	1.47	1.54	1.32	1.73	1.27	2.00	1.34	1.96	1.56	1.81	1.53
46	1.46	1.59	1.32	1.64	1.20	2.14	1.68	1.54	1.37	1.56	1.39
47	0.94	1.07	1.19	2.06	0.96	2.11	1.66	1.25	1.13	1.60	1.57
48	1.06	1.13	1.25	2.11	1.75	2.02	1.40	1.50	1.22	1.48	1.80
49	1.15	0.79	1.29	1.91	1.20	2.16	1.38	0.91	1.30	1.62	1.91
50	0.81	1.15	0.98	1.63	1.09	1.82	1.29	1.20	0.80	0.87	3.95
51	0.86	1.00	0.85	1.39	1.40	1.30	1.33	1.11	0.96	0.70	2.83
52	0.74	0.94	1.60	1.90	1.44	0.97	1.23	1.16	1.14	0.74	2.96

Table D3. (cont'd.)

Year Week No.	12 1960	13	14	15	16	17 1965	18	19	20	21	22 1970
1	2.27	0.70	0.18	1.15	0.72	0.62	0.89	0.78	0.48	0.77	1.02
2	0.77	0.98	0.78	0.73	0.90	0.68	1.27	0.73	0.73	0.65	0.98
3	0.70	0.75	0.67	1.03	0.82	0.13	0.64	0.73	0.70	0.55	0.63
4	0.54	0.44	0.48	0.82			0.59	0.81			0.61
27	0.64	0.35	1.08	1.64	0.67	0.63	0.51	1.49	0.80	0.05	
28	0.52	0.85	1.31	1.13	0.64	0.82	0.82	0.87	0.83	1.12	
29	0.63	1.16	0.89	0.81	0.82	0.35	1.07	0.91	1.28	1.18	
30	0.73	1.61	1.29	2.26	0.81	1.17	0.67	1.74	1.13	1.54	
31	1.18	1.26	1.48	1.31	1.22	1.44	1.02	1.46	1.09	1.00	
32	1.58	1.07	1.30	1.92	1.17	0.72	1.12	1.57	0.85	1.51	
33	0.75	2.12	1.29	1.78	1.48	1.03	1.64	1.31	0.51	1.23	
34	1.40	1.93	1.10	1.87	1.29	1.84	1.76	0.98	1.54	1.73	
35	1.72	1.13	1.83	1.72	0.83	1.40	1.39	1.96	1.18	1.01	
36	1.37	0.63	1.79	1.37	1.58	1.08	0.88	1.62	1.36	1.51	
37	1.72	1.77	2.04	2.02	1.73	1.17	1.36	1.76	1.71	1.46	
38	1.81	1.61	2.25	1.85	1.64	2.03	1.10	1.55	0.87	1.57	
39	1.83	1.76	1.91	1.37	1.49	1.42	1.35	2.11	1.20	1.60	
40	1.78	1.70	1.77	1.85	1.58	1.49	1.37	1.70	0.87	2.08	
41	1.50	1.22	1.82	1.61	1.57	1.79	1.68	1.83	1.41	1.77	
42	1.23	0.99	1.79	1.79	1.24	1.78	1.65	1.50	1.56	1.48	
43	1.45	0.99	1.79	1.79	1.65	1.08	1.41	1.13	1.78	1.56	
44	1.77	1.46	0.96	1.35	1.38	1.51	1.46	1.62	1.86	1.56	
45	1.30	1.44	1.44	1.37	1.52	1.29	1.02	1.64	1.44	0.96	
46	1.47	1.52	1.22	1.39	1.44	2.09	1.03	2.02	1.23	1.38	
47	1.20	1.29	1.15	1.52	1.25	1.50	1.08	1.27	1.28	1.68	
48	1.39	1.58	0.74	1.08	0.83	1.57	1.31	1.13	0.77	1.54	
49	1.26	0.96	0.96	0.70	0.77	1.21	1.07	1.02	1.13	1.04	
50	0.71	1.28	1.17	1.10	0.47	0.96	0.97	1.00	0.87	1.20	
51	0.90	0.99	0.98	1.11	0.83	1.03	0.88	0.96	0.90	0.42	
52	0.66	0.81	1.39	0.92	0.52	0.66	0.75	0.90	0.89	1.09	